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Alkalies	Fly Ash	Stationary Sources	07D	21B
Scrubbers	Dust	Alkali Scrubbing	07A	11G
Calcium Oxides	Mathematical Models	Particulate	07B	
Limestone		Venturi/Spray Tower	07G	12A
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ABSTRACT

This report presents the test results from mid-February 1976 through November 1976 of an Advanced Test Program on a prototype lime/limestone wet-scrubbing test facility for removing SO_2 and particulates from coal-fired boiler flue gases. The test facility is located at TVA's Shawnee Power Station, Paducah, Kentucky. Tests were conducted on two parallel scrubber systems, a venturi/spray tower (35,000 acfm @ 330°F) and a Turbulent Contact Absorber or TCA (30,000 acfm @ 300°F).

In short-term factorial testing (6 to 8 hours each) on both systems, SO_2 removal was determined as a function of operating parameters. These tests were conducted with lime, limestone, and limestone with added magnesium oxide.

In lime testing on both the venturi/spray tower system and the TCA system, the addition of magnesium oxide increased SO_2 removal efficiency, but in some cases increased the potential for gypsum scaling. In tests with fly-ash-free flue gas, lime utilization was higher but waste solids did not filter as well as with similar tests with flue gas containing fly ash.

In limestone testing on the TCA system, a greater concentration of magnesium ion in the slurry liquor was required to enhance SO_2 removal than in lime testing.

In flue gas characterization testing on the venturi/spray tower system, particulate mass loading, particulate size distribution, and sulfuric acid mist (SO_3) concentration were measured as a function of operating conditions. Outlet mass loadings were all within EPA New Source Performance Standards, entrainment of slurry solids was negligible, and outlet sulfuric acid mist ranged from 0 to 14 ppm.

Mathematical models were fitted to the Shawnee data and are presented for predicting SO_2 removal as a function of operating parameters for both lime and limestone scrubbing in the spray tower and in the TCA. A simplified procedure is presented for calculating gypsum saturation in the slurry liquor from analytical data.

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Section 1

SUMMARY

This is the third progress report on an Advanced Test Program under the sponsorship of the Environmental Protection Agency (EPA) to test prototype lime and limestone wet-scrubbing systems for removing sulfur dioxide (SO_2) and particulate matter from coal-fired boiler flue gases. It covers the period from mid-February 1976 through November 1976. Results of earlier testing have been reported in EPA-650/2-75-047, EPA-600/2-75-050, and EPA-600/7-76-008. The program is being conducted at a test facility operating on flue gas from Boiler No. 10 at the Tennessee Valley Authority (TVA) Shawnee Power Station, Paducah, Kentucky. Bechtel Corporation of San Francisco is the major contractor and test director, and TVA is the constructor and facility operator.

There are two parallel scrubbing systems being operated during the Advanced Test Program:

- A venturi followed by a spray tower
- A Turbulent Contact Absorber (TCA)

Each system is capable of treating approximately 10 MW equivalent (maximum rates of 35,000 acfm* @ 330°F for the venturi/spray tower and 30,000 acfm @ 300°F for the TCA) of flue gas containing 1500 to 4500 ppm of sulfur dioxide (SO_2) and 4 to 8 grains/scf of particulates. During this testing period, ductwork was installed for flue gas takeoff downstream from Boiler No. 10 particulate removal equipment. This permitted testing with relatively fly-ash-free flue gas containing 0.04 to 0.10 grain/dry scf of particulate.

Major areas of testing during this reporting period were:

- Short-term factorial tests on both scrubber systems using lime, limestone, and limestone with added magnesium oxide (MgO). These tests were made to determine SO_2 removal as a function of operating parameters
- Lime testing on the venturi/spray tower with and without added MgO and with and without fly ash in the flue gas
- Flue gas characterization testing on the venturi/spray tower to determine inlet and outlet particulate mass loading, size distribution, and SO_3 (vapor phase sulfuric acid) concentration as a function of operating conditions
- Limestone testing on the TCA with added MgO
- Lime testing on the TCA with and without added MgO

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* Although it is the policy of the EPA to use the metric system for quantitative descriptions, the British system is used in this report. Readers who are more accustomed to metric units are referred to the conversion table in Appendix A.

During this reporting period, mathematical models were developed and are presented here as an aid in predicting the following as a function of operating parameters:

- SO_2 removal for lime scrubbing in both the spray tower and the TCA
- SO_2 removal for limestone scrubbing in both the spray tower and the TCA

Finally, a simplified procedure is presented for calculating gypsum saturation from analytical data.

1.1 FACTORIAL TEST RESULTS

From mid-February through late April 1976, a series of 270 6-to-8 hour factorial tests were conducted on the venturi, the spray tower, and the TCA to determine the effect of major operating variables on SO_2 removal. Tests were conducted using lime slurry, limestone slurry, and limestone slurry with added MgO. The effect of each major variable and the operating ranges are given below:

- Increasing the scrubber inlet pH (from 5 to 6 for limestone and limestone/MgO, and 6 to 9 for lime) strongly increased SO_2 removal in all systems
- Increasing the liquor rate (from 300 to 600 gpm in the venturi, 750 to 1500 in the spray tower, and 600 to 1200 in the TCA) increased SO_2 removal in all systems

- **Increasing the gas rate (from 20,000 to 35,000 acfm @ 330° F in the venturi and spray tower and 20,000 to 30,000 acfm @ 300° F in the TCA) decreased SO_2 removal in the venturi and spray tower. In the TCA, the effect of the increasing gas rate ranged from a slight increase in SO_2 removal with limestone slurry to a slight decrease with limestone/MgO**

- **Increasing the effective* magnesium ion concentration in the scrubber liquor (from 0 to 9000 ppm) when scrubbing with limestone slurry strongly increased SO_2 removal**

- **Increasing the venturi pressure drop (from 6 to 12 inches H_2O) increased SO_2 removal**

- **Increasing the spray tower nozzle pressure drop (from 8 to 14 psi) increased SO_2 removal**

- **Increasing the TCA bed height (from 0 to 8 inches static height in each of three beds) increased SO_2 removal**

1.2 VENTURI/SPRAY TOWER LIME TEST RESULTS

From late April through early October 1976, 15 runs were made with lime slurry in the venturi/spray tower system, each lasting about 190 hours. The runs were divided into two test blocks:

- **Five runs with fly ash present in the flue gas -- all with MgO addition to the lime slurry**

- **Ten runs with fly-ash-free flue gas -- five with and five without MgO addition to the lime slurry**

*** Effective magnesium ion concentration is the concentration in excess of that required to neutralize chloride ion.**

The following conclusions were made as a result of the runs:

- Increasing the magnesium ion concentration in the scrubbing liquor increased SO_2 removal efficiency. At 2000 ppm effective magnesium ion concentration, the SO_2 removal increased by 15 to 20 percent
- Increasing the magnesium ion concentration did not always result in gypsum subsaturated operation. At 2000 ppm effective magnesium ion concentration, average gypsum saturation ranged from 15 to 105 percent
- Low gypsum saturation was consistently accompanied by high liquor sulfite concentration and high SO_2 removal efficiency
- Lower sulfite oxidation generally resulted in lower gypsum saturation, but this relationship was not always apparent
- With magnesium ion in the liquor, gypsum scaling occurred at lower gypsum saturation of the scrubber inlet liquor. At 2000 ppm effective magnesium ion concentration, scaling was observed when the gypsum saturation of the scrubber inlet liquor was as low as 80 percent, compared with about 120 percent with no effective magnesium ion
- The mist eliminator reliability with lime slurry was unaffected by the presence of magnesium ion in the liquor
- When operating with lime slurry containing 2000 ppm effective magnesium ion, the optimum scrubber inlet liquor pH appeared to be in the range of 7 to 8.
- Lime utilization in testing with fly-ash-free flue gas was better than in testing with flue gas containing fly ash. Lime utilization in fly-ash-free testing averaged 93 percent compared with 88 percent for runs made with fly ash under similar test conditions
- Fly-ash-free waste solids did not filter as well as waste solids containing fly ash. Filter cake solids contents from the fly-ash-free runs were 5 to 10 percent lower than those from the corresponding runs with fly ash
- For a given waste solids concentration, the water balance was tighter and the total dissolved solids concentration in

the slurry liquor was higher in fly-ash-free operation than in operation with fly ash because of the additional liquor associated with the fly ash in the waste solids

1.3 VENTURI/SPRAY TOWER FLUE GAS CHARACTERIZATION TEST RESULTS

From mid-October through early December 1976, a series of flue gas characterization tests were conducted on the venturi/spray tower system. During this period, particulate mass loading, particulate size distribution, and sulfuric acid mist (SO_3) concentration were measured as a function of operating conditions. The major conclusions were:

- Outlet mass loadings were all within the EPA new source performance standards, ranging typically from 0.02 to 0.04 grain/dry scf for runs with flue gas containing fly ash and 0.003 to 0.009 grain/dry scf for a run with fly-ash-free flue gas
- Outlet mass loadings and size distribution were relatively unaffected by the range of operating variables tested, including liquor rate, gas rate, slurry composition, and venturi pressure drop
- Entrainment of slurry solids must be less than the amount of total particulate emission from the fly-ash-free run (0.003 to 0.009 grain/dry scf). According to chemical analysis slurry solids made up less than 50 percent of the total particulate emission
- The data indicate that scrubber operation does not contribute to fine particle emission
- Removal of sulfuric acid mist in the scrubber appeared to be fairly constant at about 58 percent, with outlet values ranging from 0 to 14 ppm

A similar series of tests will be conducted on the TCA system in early 1977.

1.4 TCA LIMESTONE TEST RESULTS

From mid-April through the end of June 1976, eight runs were made on the TCA system with flue gas containing fly ash using limestone slurry. All but one run were made with added MgO. Average run duration was 180 hours. Major conclusions from these runs were as follows:

- A higher effective liquor magnesium ion concentration is needed in a limestone scrubbing system than in a lime scrubbing system to obtain a similar degree of improvement in SO_2 removal efficiency
- At 0, 5000, and 9000 ppm effective magnesium ion concentrations, average SO_2 removals were 77, 84, and 94 percent, respectively, under typical operating conditions
- As with lime/MgO scrubbing, gypsum scaling with limestone/MgO occurred at scrubber inlet liquor gypsum saturations as low as 80 percent
- MgO addition at the levels tested did not always result in gypsum subsaturated operation. Lower saturation levels usually increased the liquor sulfite concentration and the SO_2 removal efficiency

1.5 TCA LIME TEST RESULTS

From July through November 1976, the TCA system was operated with lime slurry and flue gas containing fly ash. Of a total of 18 runs averaging 160 hours per run, all but two runs were conducted with added MgO. Chemically, the results were similar to the lime/MgO runs on the venturi/spray tower system. Additional conclusions were:

- Gypsum scaling occurred at scrubber inlet liquor saturations as low as 75 percent during runs with MgO addition
- About 80 percent SO_2 removal (2800 ppm inlet) was achieved in the TCA using lime slurry without MgO addition. Minor gypsum scaling occurred with 8 percent solids in the recirculated slurry; no scaling occurred with 15 percent solids

1.6 DATABASE

A computerized database has been developed which contains run descriptions and analytical data for all runs conducted at the Shawnee Test Facility since April 1974 for the venturi/spray tower system and August 1974 for the TCA system. Current test results are added to the database on a daily basis.

Data can be selectively retrieved from the database, reports can be produced, and graphical correlations among variables or groups of variables can be plotted directly by anyone with an appropriate time-sharing terminal. This database is available to the public, and its use by any interested party can be arranged.

1.7 SIMPLIFIED EQUATION FOR THE CALCULATION OF GYPSUM SATURATION

In testing at Shawnee, the Bechtel-Modified Radian Equilibrium Computer Program has always been the standard for calculating calcium sulfate (gypsum) saturation from analytical data in lime and limestone wet-scrubbing liquors. Simplified equations have been developed by Bechtel that predict gypsum saturation within 8 percentage points (and usually better) of the value calculated by the Bechtel-Modified Radian Program for the range of test conditions encountered at Shawnee. At 50°C the equation is as follows:

$$\text{Fraction gypsum Saturation at } 50^{\circ}\text{C} = (\text{Ca})(\text{SO}_4)\left[\frac{263}{I} + 47\right]$$

where

$I = 3\,[(\text{Ca}) + (\text{Mg})] + (\text{SO}_4)$

= ionic strength of the liquor, assuming the liquor contains only Ca^{++}, Mg^{++}, and $SO_4^{=}$ ions in solution

(Ca)
(Mg) = measured dissolved concentrations of total calcium, magnesium, and sulfate species, respectively, g-mole/liter
(SO_4)

This simplified equation is being used to generate the gypsum saturation values listed in the Shawnee database.

1.8 MATHEMATICAL MODELS FOR SO_2 REMOVAL

A semitheoretical model has been developed and fitted to the Shawnee test data for predicting SO_2 removal by lime or limestone wet scrubbing from operating variables in a spray tower or a TCA. This model accounts for all major variables investigated at the Shawnee Test Facility except for possible effects of liquor sulfate (gypsum) saturation or sulfite oxidation on SO_2 removal with magnesium ion in the scrubber liquor. Such effects are relatively insignificant at low magnesium ion concentrations. The fitted equations are as follows:

1.8.1 Spray Tower Equation for SO_2 Removal by Limestone Slurry

$$\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\left\{ - 9.8 \times 10^{-5} (L/G)^{0.92} v^{0.19} \exp\left[pH_i + 1.35 \times 10^{-4} (Mg)_e - 1.7 \times 10^{-4} (SO_2)_i + 1.45 \times 10^{-5} Cl \right] \right\}$$

1.8.2 TCA Equation for SO_2 Removal by Limestone Slurry

$$
\begin{aligned}
\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\Bigg\{ & - 2.05 \times 10^{-4} (L/G)^{0.81} v^{0.36} \\
& \exp\Bigg[4.3 \times 10^{-3} v\left(\frac{h_{tot}}{d_s} + N_G\right) + 0.81\, pH_i \\
& + 7.9 \times 10^{-5} (Mg)_e - 1.7 \times 10^{-4} (SO_2)_i \\
& + 1.3 \times 10^{-5}\, Cl \Bigg]\Bigg\}
\end{aligned}
$$

1.8.3 Spray Tower Equation for SO_2 Removal by Lime Slurry

$$
\begin{aligned}
\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\Bigg\{ & - 0.0020 (L/G) \exp\Bigg[0.29\, pH_i \\
& + 2.8 \times 10^{-4} (Mg)_e + 4.7 \times 10^{-5}\, Cl \Bigg]\Bigg\}
\end{aligned}
$$

1.8.4 TCA Equation for SO_2 Removal by Lime Slurry

$$
\begin{aligned}
\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\Bigg\{ & - 0.0010 (L/G)^{1.12} v^{0.65} \\
& \exp\Bigg[0.18\, pH_i + 1.5 \times 10^{-4} (Mg)_e \\
& - 2.2 \times 10^{-4} (SO_2)_i + 0.00392\, v\left(\frac{h_{tot}}{d_s} + N_G\right)\Bigg]\Bigg\}
\end{aligned}
$$

where

Cl = measured total dissolved chloride ion concentration, ppm

d_s = diameter of the TCA sphere (1.5 inches at Shawnee)

h_{tot} = total height of spheres in the TCA, inches (zero for spray tower)

L/G = liquid-to-gas ratio in the scrubber (125 °F, humidified gas), gal/Mcf

$(Mg)_e$ = effective magnesium ion concentration, ppm
= $[\text{ppm } Mg^{++} - (\text{ppm } Cl^- / 2.92)]$ for $Mg^{++} > Cl^- / 2.92$
= 0 for $Mg^{++} \leq Cl^- / 2.92$
where 2.92 = ratio by weight of Cl^- to Mg^{++} in $MgCl_2$

N_G = number of grids or screens in the TCA, four at Shawnee (zero for the spray tower)

pH_i = scrubber inlet liquor pH

$(SO_2)_i$ = inlet gas SO_2 concentration, ppm

v = gas velocity in scrubber (125 °F, humidified gas), ft/sec

These equations have been verified only for the range of conditions encountered at the Shawnee Test Facility. Extrapolation beyond this range is not recommended.

1.9 LABORATORY QUALITY ASSURANCE PROGRAM

A continuing laboratory quality assurance program has resulted in several changes for improving analytical results.

The stoichiometric ratio of moles of calcium added per mole of SO_2 absorbed is now calculated from solids analysis by the equation

$$\text{SRCO3} = 1 + \frac{\text{Carbonate}}{\text{Total Sulfur}} \quad \text{(designated SRCO3 in the database)}$$

instead of the previously used equation

$$\text{SR} = \text{Calcium/Total Sulfur} \quad \text{(designated SR in the database)}$$

Although, in theory, the two relationships should give identical values, the stoichiometric ratio based on carbonate is more accurate at low stoichiometries.

Laboratory measurement of pH in the slurry liquor has been improved by storing the electrodes in a hot buffered solution saturated with potassium chloride, switching electrodes at the beginning of each 8-hour shift, using only electrodes with glass-to-glass seals, and employing a pH meter with a digital readout.

Interference by fly ash has been reduced in the primary procedure (X-ray fluorescence) for calcium and total sulfur in solids by diluting the sample with lithium carbonate.

The primary procedure for sulfite analysis in both solids and liquids has been improved by using a Wallace and Tiernan Amperometric Titrator.

A new turbidimetric procedure is being tested for use as the primary procedure for total sulfur in liquors and the backup procedure for total sulfur in solids. If successful, this procedure will replace the present titrimetric method.

A new method for carbonate in solids using the laboratory's Oceanography International Carbon Analyzer is being evaluated as a primary procedure to replace the present volumetric CO_2 evolution procedure.

Atomic absorption spectrometry, the primary procedure for calcium and magnesium in liquors, is precise and accurate at low magnesium concentrations. However, precision is reduced by the large dilutions required at high levels of magnesium. Titration with EDTA (ethylenediamine-tetraacetic acid or its salts) is being examined as an alternative method for high magnesium concentrations.

1.10 SLUDGE CHARACTERIZATION

In addition to the TVA and Aerospace sludge characterization and disposal programs reported elsewhere, a program to routinely monitor sludge settling and dewatering characteristics has been established. For each run, at least two scrubber slurry samples are taken for cylinder settling tests and funnel filtration tests. These tests have been useful in monitoring both clarifier and rotary drum vacuum filter performance. It has been observed that:

- Initial settling rate increases with decreasing initial percent solids over all the run conditions investigated
- Filter cake solids concentration is higher for lime tests with fly ash than without fly ash. Values ranged from 49 to 56 percent for fly ash tests and from 42 to 48 percent for tests without fly ash

1.11 OPERATING EXPERIENCE

1.11.1 Scrubber Internals

The strong correlation between high alkali utilization and clean mist eliminator operation has been further confirmed during this testing period.

TCA grid supports have shown no evidence of significant erosion in 22,000 hours of slurry service.

Solid nitrile foam spheres used in the TCA have been in service for approximately 3900 hours with no significant failures. A continual decrease in diameter, however, has made it necessary to periodically add more spheres to maintain static bed height.

Bete No. ST48FCN stellite-tipped nozzles logged 17,500 hours of slurry service in the spray tower before their replacement in December 1976.

Although they were still functional at the time of replacement, the nozzle diffusers had lost 26 percent of their original thickness.

Spraco No. 1969F 316 stainless-steel full-cone nozzles, used for TCA slurry feed, have logged 15,000 hours of operation at 5 psi pressure drop with no significant wear.

Bete No. ST32FCN stellite-tipped nozzles used to spray slurry for cooling the inlet gas to the TCA showed significant wear after 11,600 hours of continuous service and were replaced.

Venturi internals continued to erode significantly in several locations, but the venturi operability has not been affected.

1.11.2 Reheaters

The in-line reheaters modified to incorporate fuel-oil-fired external combustion chambers have operated reliably for over 19,300 hours in the venturi/spray tower system and 8000 hours in the TCA system.

1.11.3 Fans

As in the past, fan reliability has been good during the current operating period.

1.11.4 Pumps

The major pump problem has been pump-seal failure in the rubber-lined slurry pumps with air-flushed packings. Air-flushed packings are used on major pumps at the test facility to avoid the effect of seal water intrusion on the scrubber water balance.

1.11.5 Waste Solids Handling

Cloth life in the rotary-drum filter has been extended by welding the cake deflector blade adjustment to prevent the blade from contacting the cloth. The present best service life of a filter cloth was about 850 hours. Because of the design of the Shawnee filter, the reported cloth life may not be representative of the life of a cloth in a well designed commercial unit.

The centrifuge has operated well for 3350 hours since the wear areas were resurfaced with colmonoy and stellite No. 1016 in May 1976.

No significant mechanical problems were encountered in the clarifier during this reporting period.

1.11.6 Alkali Addition Systems

The lime addition system has given excellent reliability in over 22,500 hours of intermittent operation.

The limestone addition system has given satisfactory performance with low maintenance during the entire alkali wet-scrubber test program. The most significant maintenance items are the Moyno pumps that feed 60 weight percent limestone slurry. In these pumps, operating life has been short, typically 2000 hours for a rotor and 1000 hours for a stator.

1.11.7 Instrument Operating Experience

The main problem associated with the Uniloc Model 321 submersible pH meters used to measure scrubber liquor pH has been occasional scale formation on the probes.

Satisfactory accuracy of the Foxboro magnetic flow meters has been maintained by electrical purging once per shift and flow checks approximately once every 3 months. No liner failures in the meters, which had been experienced in the past, were encountered during this reporting period.

When operating properly, the Brooks Maglink 5300 series level indicators are capable of measuring slurry level in the effluent hold tanks to within 6 inches. However, occasionally the float will get stuck or uncouple from the magnet.

Du Pont Model 400 UV SO_2 analyzers have operated trouble-free, with routine calibration three times a week.

Dynatrol density meters have operated trouble-free.

Modification of spare Du Pont SO_2 meters to measure nitrogen dioxide (NO_2) has been unsuccessful. The problem has been referred to Du Pont.

1.11.8 Mechanical Components Evaluation

Selected mechanical components are being continually evaluated at the Shawnee Test Facility. These include plastic pipe, line strainers, butterfly and knife gate valves, control valves, mechanical seals, a sonic tank level sensor, a Brook tank level sensor, a Metritape tank level sensor, and several Ceilcote lining materials.

Section 2

INTRODUCTION

In June 1968, a program was initiated under the direction of the Environmental Protection Agency (EPA)* to test prototype lime and limestone wet-scrubbing systems for removing SO_2 and particulates from flue gases. A test facility was built which operates with flue gas from coal-fired Boiler No. 10 at the Tennesee Valley Authority (TVA) Shawnee Power Station, Paducah, Kentucky. Bechtel Corporation of San Francisco was the major contractor and test director, and TVA was the constructor and facility operator.

Initially, the test facility consisted of three parallel scrubber systems: a venturi followed by a spray tower, a Turbulent Contact Absorber (TCA), and a Marble-Bed Absorber. Testing of the Marble-Bed Absorber was discontinued in July 1973 because of operational problems. These systems were chosen for their ability to remove both SO_2 and particulates from the burning of medium- to high-sulfur coal. Each system has a capacity of approximately 10 MW equivalent of flue gas (35,000 acfm @ 330°F for the venturi/spray tower and 30,000 acfm @ 300°F for the TCA). The systems operate with flue gas containing 1500 to 4500 ppm of SO_2 obtained either upstream (4 to 8 grains/dry scf of particulates) or downstream (0.04 to 0.10 grain/dry scf of particulates) from the Boiler No. 10 particulate removal equipment.

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* The National Air Pollution Control Administration prior to 1970

The original testing program at the facility lasted from March 1972 to October 1974. Results are presented in Reference 1. During the original program, emphasis was placed on demonstrating reliable operation. The most significant reliability problem was associated with scaling and/or plugging of mist elimination surfaces. The TCA mist elimination system consisted of a wash tray in series with a chevron mist eliminator, both with underside washing. Long-term operability of this system was demonstrated in limestone service in an 1835-hour test at a scrubber gas velocity of 8.6 ft/sec*. The venturi/spray tower mist elimination system consisted of a chevron mist eliminator with underside washing. At the end of the original testing program, long-term operability of the venturi/spray tower system had not been demonstrated.

In June 1974, the EPA, through its Office of Research and Development and Control Systems Laboratory, initiated a 3-year Advanced Test Program at the Shawnee Facility. Bechtel Corporation continued as the major contractor and test director, and TVA as the constructor and facility operator.

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* In this report, all gas velocities and liquid-to-gas ratios are at scrubber operating conditions, i.e., saturated gas at scrubber temperature. The scrubber temperature is approximately 125°F under normal operating conditions. The gas velocities are all superficial velocities.

The major goals established for the advanced program were:

- To continue long-term testing, with emphasis on demonstrating reliable operation of the mist elimination system
- To investigate advanced process and equipment design variations for improving system reliability and process economics
- To perform long-term (2- to 5-month) reliability testing on promising process and equipment design variations
- To improve waste sludge disposal characteristics

The results of advanced testing from October 1974 through April 1975 at the Shawnee Facility are presented in Reference 2. During this period, successful operation of a chevron mist eliminator with intermittent top and bottom wash was demonstrated in the venturi/spray tower system in lime service at a superficial scrubber gas velocity of 8.0 ft/sec. In the TCA in limestone service, plugging of the combined wash tray/mist eliminator system was a continual problem at velocities greater than 8.6 ft/sec. Tests were interrupted in May 1975 for a 6-week scheduled maintenance outage on Boiler No. 10.

The results of advanced testing at the Shawnee Facility from June 1975 through mid-February 1976 are presented in Reference 3. During this period, the wash tray/mist eliminator system on the TCA was discontinued in favor of a chevron mist eliminator similar to the one used in the venturi/spray tower. Both systems operated mainly at their maximum fan capacity (9.6 ft/sec superficial gas velocity in the spray tower and 12.5 ft/sec in the TCA). Significant results were:

- The development of the relationship between alkali utilization and other parameters on both scrubber systems in limestone service
- The discovery that alkali utilization strongly affects mist eliminator reliability -- the mist eliminator is easier to keep clean at high utilization
- The demonstration that above 85 percent alkali utilization, an intermittent bottom wash will keep the mist eliminator free of soft solids (raw water at 1.5 gpm/ft^2 for 6 minutes every 4 hours)
- The demonstration that below 85 percent alkali utilization, a continuous bottom wash will limit soft solids accumulation to less than 10 percent mist eliminator restriction (combined raw water and clarifier return liquor at 0.4 gpm/ft^2)
- The demonstration that intermittent top wash prevents scale formation on top mist eliminator blades (raw water for 4 minutes every 8 hours at 0.5 gpm/ft^2)
- The demonstration on the TCA that three hold tanks in series improves limestone utilization -- at 85 percent SO_2 removal, limestone utilization was improved from about 60 percent with a single hold tank to about 75 percent with three tanks in series
- The demonstration in an 1143-hour run that the venturi/spray tower in lime service can operate smoothly with a gas rate following a daily boiler cycle from 40 to 100 percent of full load

This Advanced Program Third Progress Report presents the results of testing at the Shawnee Facility from mid-February 1976 through November 1976.

During this period, a total of 270 short (6 to 8 hours) factorial tests were run on both scrubber systems using lime slurry, limestone slurry, and limestone slurry with added MgO. These tests were designed to relate SO_2 removal to major process variables.

On the venturi/spray tower system, 16 longer runs of 4 to 8 days each were made to explore operating variables under several modes of operation. Lime slurry was tested using fly-ash-free flue gas. Lime slurry with added magnesium oxide to enhance removal was tested using both fly-ash-free flue gas and flue gas containing fly ash. One test was run with limestone slurry using fly-ash-free flue gas.

In addition, a series of nine lime runs of 2 to 6 days each were made on the venturi/spray tower during which data characterizing flue gas mass loading, particulate size distribution, and SO_3 concentration at the inlet and outlet of the scrubber were collected.

It should not be assumed that the entire range of operating configurations and conditions tested at the Shawnee facility is free of patent restrictions. Before making commercial use of the Shawnee test results, the patent situation should be reviewed.

On the TCA system, 26 longer runs of 4 to 8 days each were made. These included runs with lime and limestone slurry, with and without added magnesium oxide, using flue gas with and without fly ash.

In addition to test results, this Third Progress Report presents mathematical models fitted to the Shawnee test data for predicting SO_2 removal by lime or limestone wet scrubbing in both the spray tower and the TCA.

Also, a simplified procedure is presented for calculating calcium sulfate (gypsum) saturation in the scrubber inlet liquor from analytical data.

Other topics presented in this report include an introductory discussion of lime/limestone wet scrubbing chemistry, a description of the Shawnee database, a discussion of the laboratory quality assurance program, results of the sludge characterization program, and a discussion of operating experience during this reporting period.

Section 3

TEST FACILITY

Two parallel scrubbing systems are being operated during the Advanced Test Program. Scrubbers incorporated in these systems are:

- A venturi followed by a spray tower
- A Turbulent Contact Absorber (TCA)

Each system operates independently and is capable of treating approximately 30,000 acfm of flue gas from the coal-fired Boiler No. 10 at TVA's Shawnee Power Station. This gas rate is equivalent to approximately 10 MW of power plant capacity.

Boiler No. 10 normally burns a medium- to high-sulfur bituminous coal which produces SO_2 concentrations of 1500 to 4500 ppm in the flue gas. Ductwork to the scrubbers is tied in both upstream and downstream of the Boiler No. 10 particulate removal equipment allowing scrubber operation on flue gas with high fly ash loadings (4 to 8 grains/dry scf) or low fly ash loadings (0.01 to 0.05 grain/dry scf).

3.1 SCRUBBER SELECTION

The major criterion for scrubber selection was the potential for removing both SO_2 and particulates at high efficiencies (defined for Shawnee Facility as SO_2 removal greater than 80 percent and particulate removal greater than 99 percent). Other criteria considered in the selection of the scrubbers were:

- The ability to handle slurries without plugging or excessive scaling
- Reasonable cost and maintenance
- Ease of control
- Reasonable pressure drop

The venturi/spray tower and the TCA were chosen to meet these criteria.

The adjustable-throat venturi scrubber in the venturi/spray tower system was manufactured by Chemical Construction Company. The venturi scrubber removes the bulk of the particulates. But because the residence time in a venturi scrubber is low, SO_2 removal with lime/limestone slurry is inadequate. The spray tower that follows the venturi scrubber provides additional capacity for the removal of SO_2.

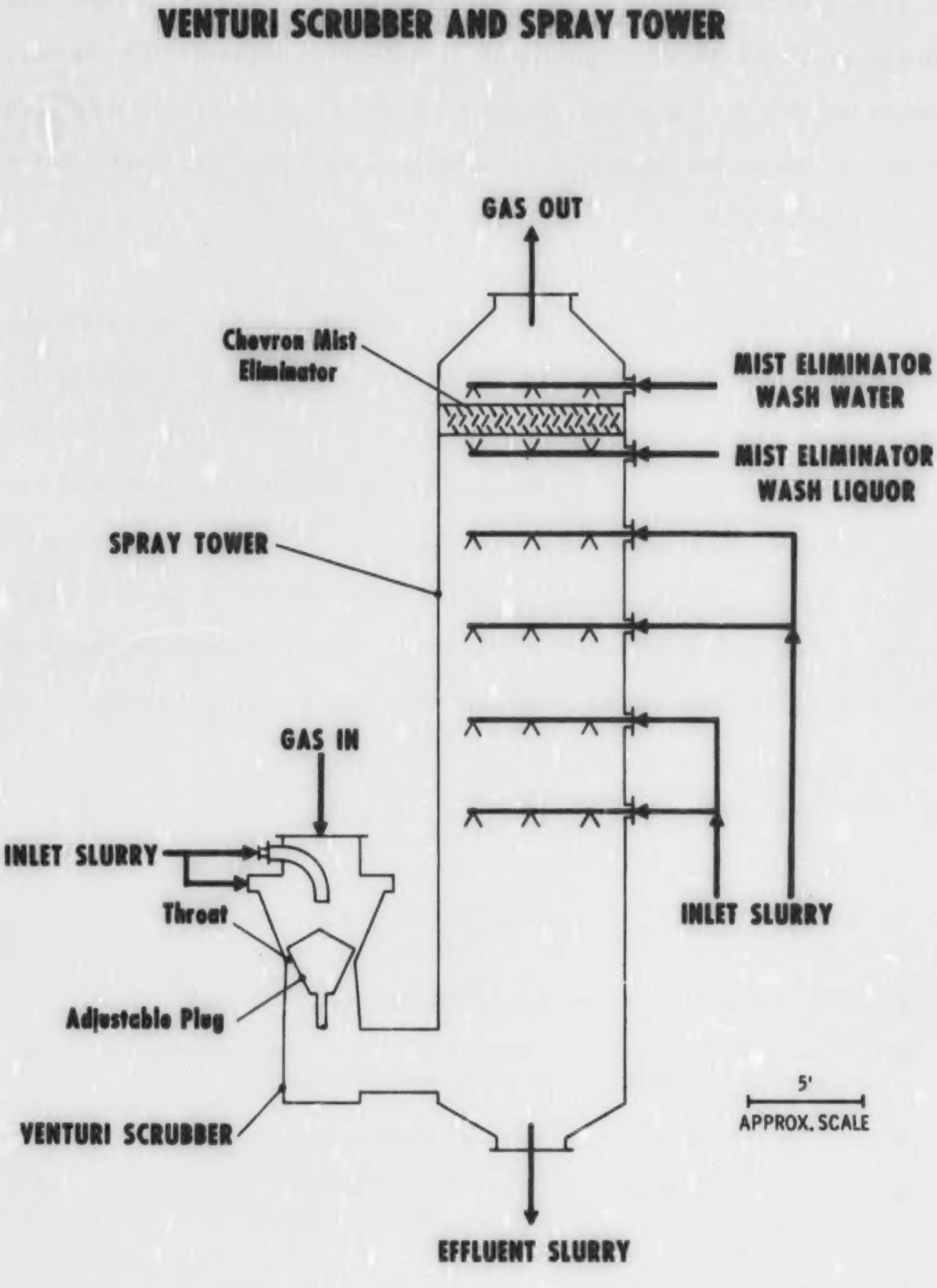
The TCA was manufactured by Universal Oil Products. It operates with up to three beds of nominally 1-1/2-inch-diameter low-density spheres that are free to move between retaining grids. As the incoming flue gas contacts the slurry in these beds, both SO_2 and particulates are removed.

Figures 3-1 and 3-2 (drawn with major dimensions to scale) show the two scrubber systems and the mist elimination system selected for deentraining slurry in the exit gas streams. The chevron mist eliminator used on the two scrubber systems during this testing period is depicted, to scale, in Figure 3-3. The cross-sectional area of the spray tower is 50 ft^2 in both the scrubbing section and the mist eliminator section. The cross-sectional area of the TCA scrubber is 32 ft^2 in the scrubbing section and 49 ft^2 in the mist eliminator section.

3.2 SYSTEM DESCRIPTION

The Shawnee Test Facility contains five major areas:

- The scrubber area (including tanks and pumps)
- The operations building area (including laboratory area, electrical gear, centrifuge, and filter)
- The thickener area (including tanks and pumps)
- The utility area (including air compressors, air dryer, limestone storage silos, mix tanks, gravimetric feeder, and pumps)
- The pond area



VENTURI SCRUBBER AND SPRAY TOWER

Figure 3-1. Schematic of Venturi Scrubber and Spray Tower

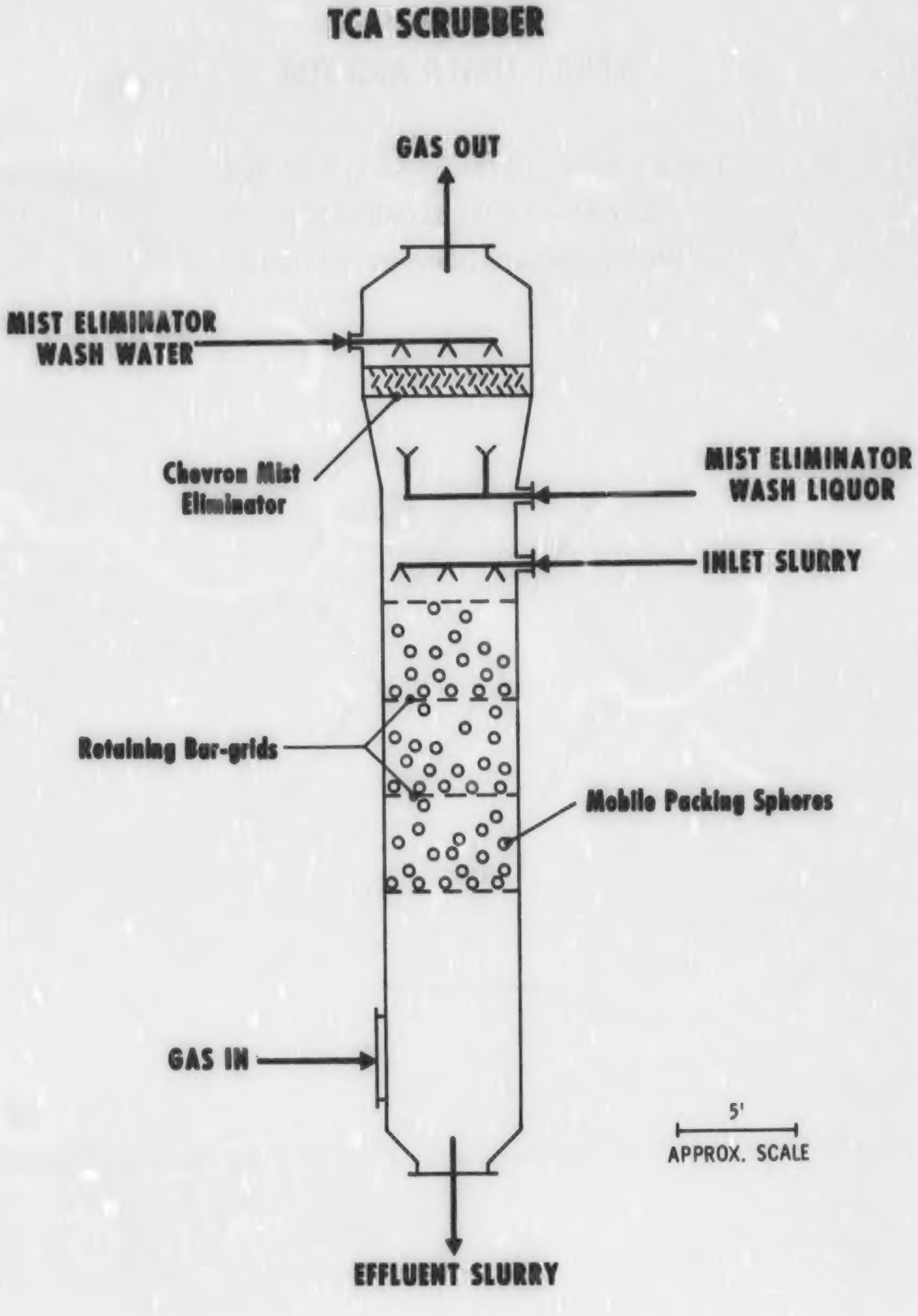


Figure 3-2. Schematic of Three-Bed TCA

SPRAY TOWER AND TCA

THREE - PASS, OPEN - VANE, 316L S.S.
CHEVRON MIST ELIMINATOR
(HORIZONTAL CONFIGURATION)

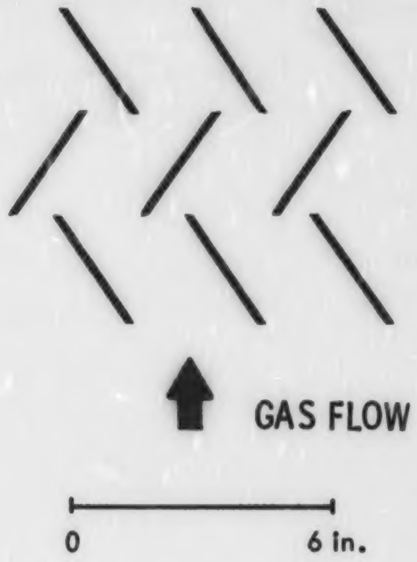


Figure 3-3. Test Facility Mist Eliminator Configuration

The test facility has been designed so that a number of different scrubber internals and piping configurations can be used with each scrubber system. For example, the TCA scrubber can be operated with one, two, or three beds of spheres or with only the support grids. Waste solids separation can be achieved with a clarifier alone or with a clarifier in combination with a filter or a centrifuge. Either system can be operated with a single hold tank or with up to three tanks in series.

Typical system configurations depicting lime testing with the venturi/spray tower and limestone testing with the TCA scrubber are illustrated schematically in Figures 3-4 and 3-5, respectively. Such process details as flue gas saturation (humidification) sprays are not shown.

In May-June 1976, the ductwork to the scrubber systems was modified so that gas can be withdrawn from the boiler either before the steam plant particulate removal equipment or after it. In the former configuration, all the entrained particulate matter (fly ash) is introduced into the scrubber; in the latter, the gas to the scrubber contains only a residual amount of fly ash. The gas flow rate to each scrubber is measured by venturi flow meters and controlled by dampers on the induced-draft fans. The concentration of SO_2 in the inlet and outlet gas streams is monitored continuously by Du Pont photometric analyzers.

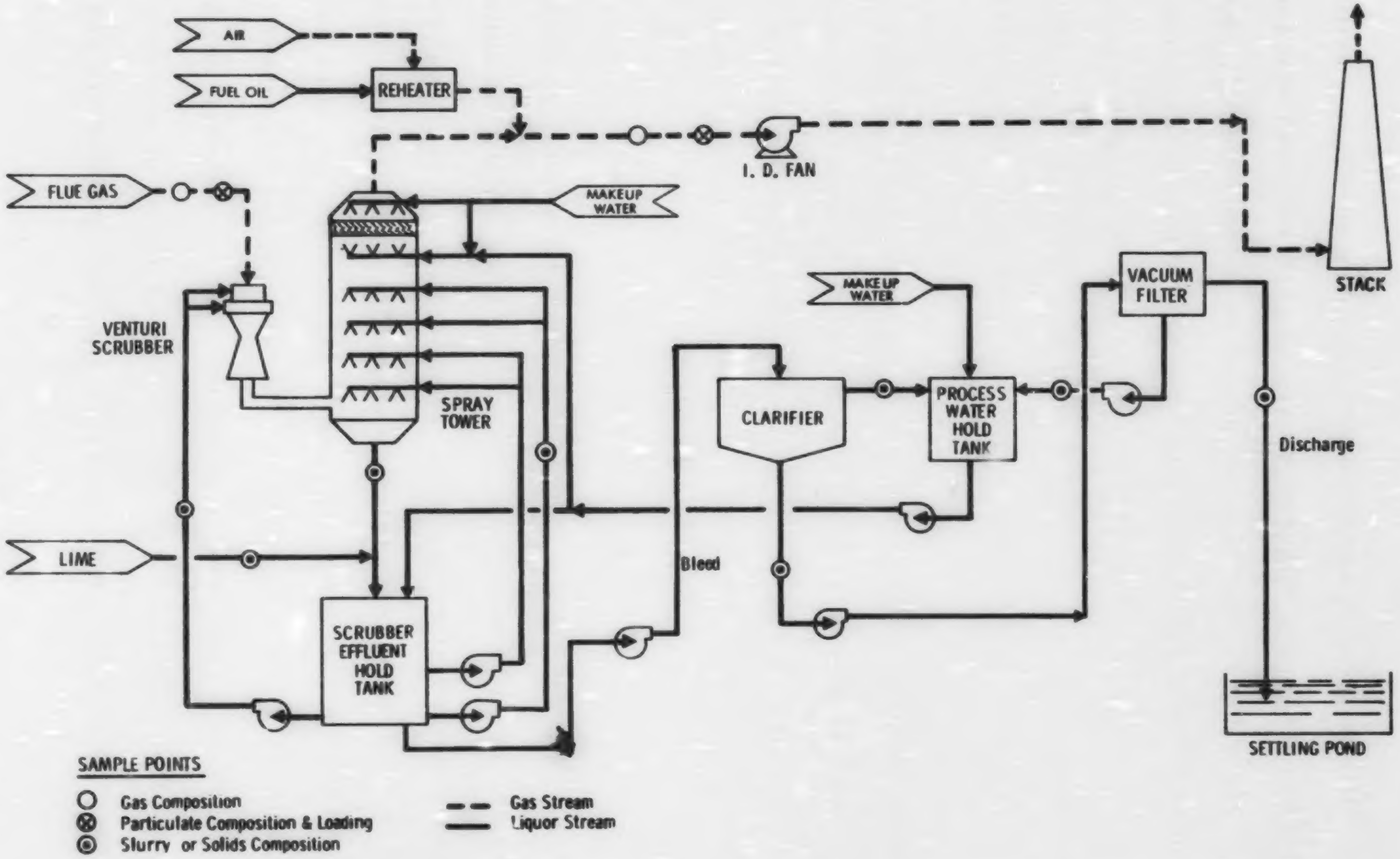


Figure 3-4. Typical Process Flow Diagram for Venturi/Spray Tower System

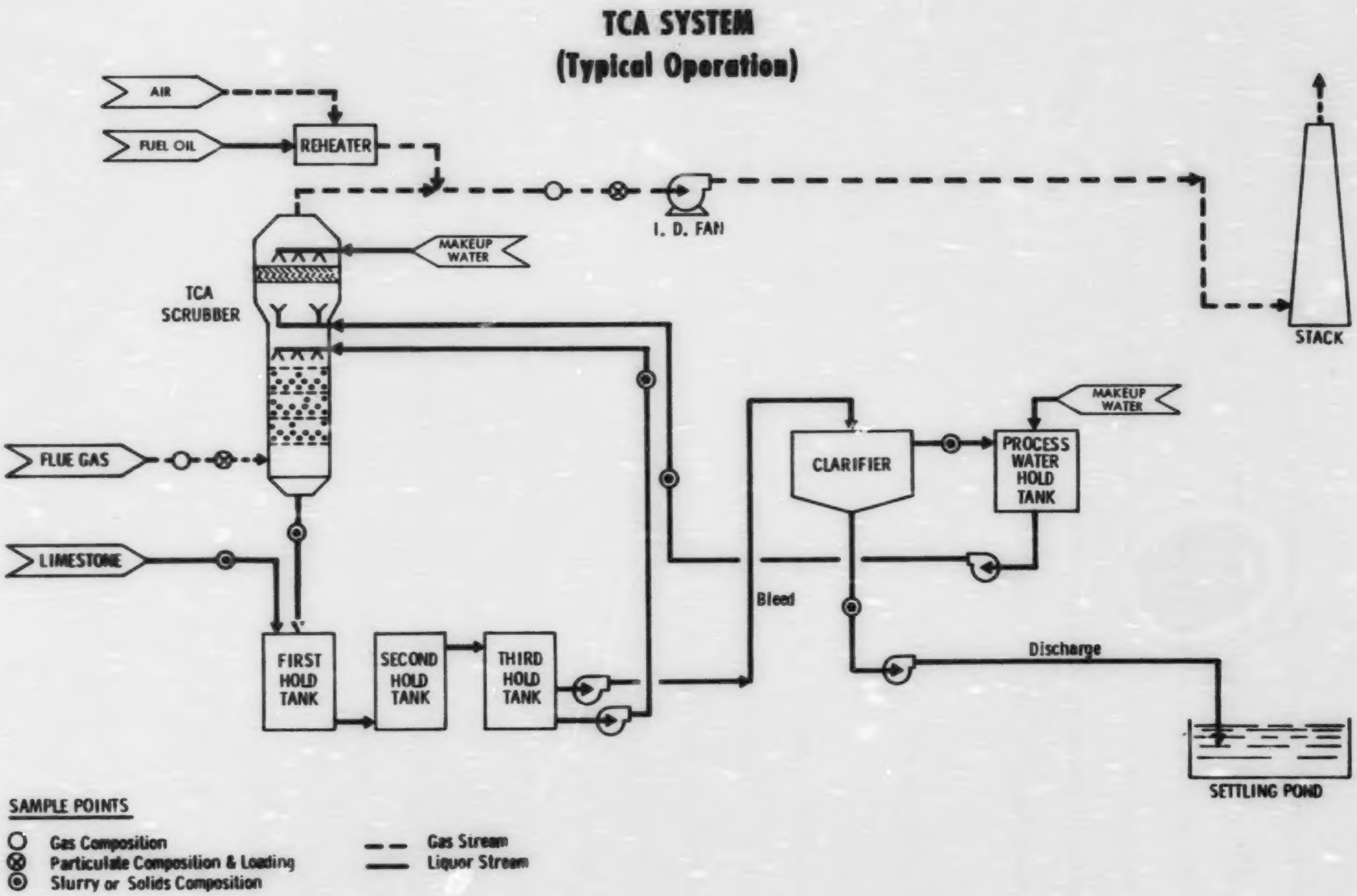


Figure 3-5. Typical Process Flow Diagram for TCA System

The scrubbing systems are controlled from a central graphic panelboard, where all significant process variables are on digital display. Important process control variables are continuously recorded. Trend recorders are provided for periodic monitoring of selected data sources. Chemical composition of major streams and scrubber inlet liquor pH are determined several times a day.

3.3 EPA PILOT PLANT

There are two smaller scrubbing systems (300 acfm each) at the EPA Industrial Environmental Research Laboratory in Research Triangle Park, North Carolina. These small, pilot-scale scrubber systems are capable of simulating the Shawnee scrubber systems with excellent agreement in the lime/limestone wet-scrubbing chemistry. Preliminary data are generated on the pilot-scale system to determine the validity of new concepts and to guide the selection of those promising concepts that should logically be investigated on the larger scale Shawnee units. Examples of studies originating at the EPA pilot plant and then later investigated at the Shawnee test facility include gypsum unsaturated operation (Reference 4), increasing limestone utilization (Reference 5), and forced oxidation (Reference 6).

Section 4

TEST PROGRAM

This section contains a description of the Shawnee Advanced Test Program, which began in June 1974 and is scheduled to run through February 1978.

4.1 TEST PROGRAM OBJECTIVES AND SCHEDULE

The objectives of the Advanced Test Program are:

- To demonstrate process reliability, with an emphasis on mist elimination systems
- To investigate advanced process and equipment design variations for improving system reliability and economics
- To evaluate process variations for a substantial increase in alkali utilization for limestone systems
- To evaluate the effect of increased magnesium ion concentration on improving control, reducing gypsum saturation, and increasing SO_2 removal
- To evaluate the efficiency and reliability of lime and limestone scrubbers under conditions of widely varying flue gas flow rate and inlet SO_2 concentration
- To evaluate system performance and reliability without fly ash in the flue gas

- To determine the effectiveness of forced oxidation in producing an improved throwaway sludge product
- To determine the practical upper limits of SO_2 removal efficiency for both limestone and lime scrubbing systems
- To evaluate the TCA performance with lime and the venturi/spray tower performance with limestone
- To perform reliability demonstration runs on advanced process and equipment design variations
- To characterize stack gas emissions, including inlet and outlet particulate mass loading and size distribution, slurry entrainment, and total sulfate emissions
- To evaluate methods of automatic control
- To provide material for the field evaluation of sludge disposal processes. (The field evaluation is being conducted under a separate EPA program)
- To evaluate corrosion and wear of alternative plant equipment components and materials
- To develop a computer program for the design and cost comparison of full-scale lime and limestone systems

The test program schedule based on the defined objectives is presented in Figure 4-1. The period covered by the Third Progress Report extended from mid-February 1976 through November 1976. In the venturi/spray tower during this period, both short, factorially designed tests (~8 hours/test) and longer term tests (~1 week/test) were run. The longer-term tests, conducted with lime slurry, were run to investigate the effects of MgO addition and the presence, or absence, of fly ash. In addition, data characterizing mass loading were collected during some lime runs.

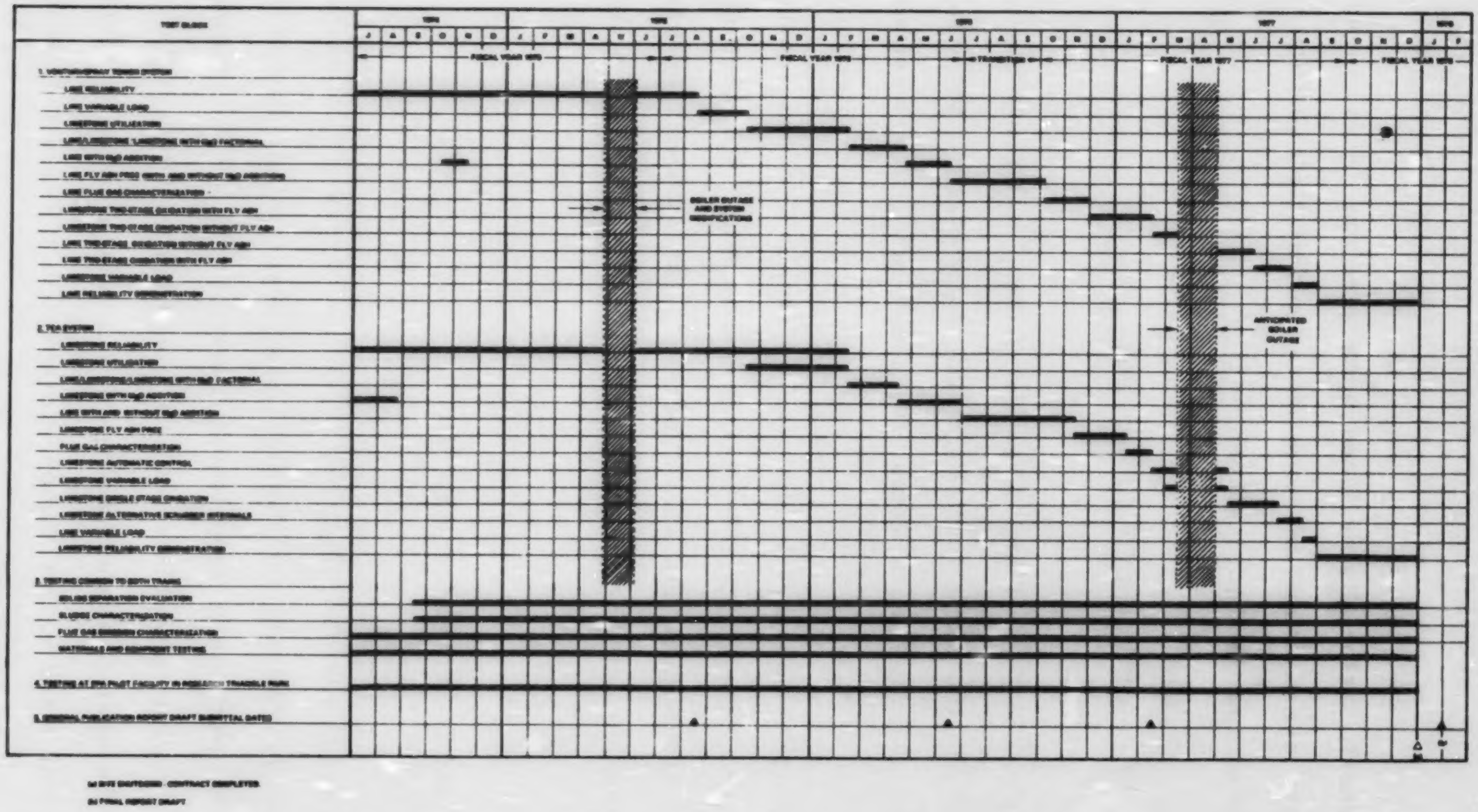


Figure 4-1. Shawnee Advanced Test Schedule

In the TCA, short, factorially designed tests were run. Also run were long-term tests investigating limestone operation with MgO addition and lime operation with and without MgO addition.

4.2 CLOSED-LIQUOR-LOOP OPERATION

A closed liquor loop is achieved when the makeup water input to the system is equal to the water normally exiting the system in the settled sludge and in the humidified flue gas. In this report, it was assumed that a closed liquor loop is achieved when the solids concentration of the purged sludge is 38 percent by weight or higher and no separate liquor is purged. Except for a 3-week period in May 1976 when discharge solids dropped as low as 32 percent, the advanced program tests have been conducted in closed-liquor-loop operation as defined above.

4.3 ANALYTICAL PROGRAM

During the testing, samples of slurry, flue gas, limestone, lime, and coal are taken periodically for chemical analyses, and samples of flue gas are taken for particulate mass loading determinations. The locations of slurry and gas sample points are shown on Figures 3-4 and 3-5. A summary of the analytical methods for determining important species in the slurry solids and slurry liquor is presented in Table 4-1. A lab-

Table 4-1

FIELD METHODS FOR BATCH CHEMICAL ANALYSIS OF SLURRY AND ALKALI SAMPLES

SPECIES	FIELD METHODS			
	SOLIDS		LIQUIDS	
	Primary Method	Backup Method	Primary Method	Backup Method
Sodium	--	--	Atomic absorption	--
Potassium	--	--	Atomic absorption	--
Calcium	X-ray fluorescence	Atomic absorption	Atomic absorption	--
Magnesium	--	--	Atomic absorption	--
Sulfite	Amperometric titration	--	Amperometric titration	--
Total sulfur	X-ray fluorescence	Titration	Titration	--
Carbonate	CO_2 evolution	--	--	--
Chloride	--	--	Potentiometric titration	Mercuric nitrate titration

oratory procedures manual (Reference 7) was issued in March 1976. A listing of the compositions of the raw materials used in the testing program is presented in Appendix C.

Four Du Pont photometric analyzers are used for continuous SO_2 gas analyzing one each at the inlet and outlet of each scrubber. Scrubber inlet liquor pH is continuously monitored with Universal Interloc pH analyzers. Both scrubber inlet and outlet liquor pH are monitored periodically by the laboratory. A modified EPA particulate train (manufactured by Aerotherm/Acurex Corporation) is used to measure mass loading at scrubber inlets and outlets.

4.4 DATA ACQUISITION AND PROCESSING

Data recorded by onsite personnel are sent to the Bechtel Corporation offices in San Francisco for processing. Data from the test facility are entered into a computerized database in San Francisco. The data are sorted, further calculations made (e.g., percent sulfite oxidation, stoichiometric ratio), and tables prepared that present the data covering a specified period for a given scrubber. The database tables for mid-February 1976 through November 1976 are presented in Appendix D.

4.4.1 Analytical Data

The analytical data acquisition system, which records the results of laboratory analyses on printed summary sheets, was designed and (in part) installed by Radian Corporation. A minicomputer is used to perform certain calculations and print the resultant data on a summary sheet, which is then transferred to San Francisco for inclusion in the master database.

Section 5

SUMMARY OF THE CHEMISTRY OF SO_2 REMOVAL BY LIME OR LIMESTONE WET SCRUBBING

In this section, a simplified description of the chemistry of SO_2 scrubbing is presented to provide an aid in understanding the Shawnee test results. The basic lime and limestone scrubbing processes are described first, followed by a discussion of the effects on SO_2 removal of added "effective" magnesium ions, sulfite oxidation, and gypsum saturation.

The chemistry described was derived from several sources and is not wholly based on results at the Shawnee Test Facility. Sources were documented if possible. Details of the chemistry presented are based on interpretation of observations to date and are subject to modification as more information becomes available.

5.1 SCRUBBING WITH LIME

The overall reaction of lime with SO_2 may be represented by:

$$CaO + SO_2 \rightarrow CaSO_3 \qquad (5.1)$$

One mole of lime reacts with one mole of sulfur dioxide to produce one mole of calcium sulfite. The product is actually a mixture of calcium sulfite hemihydrate ($CaSO_3 \cdot 1/2H_2O$) and the oxidation product, calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$).

The detailed chemistry of this process is complex, involving mass transfer between the gas, liquid, and solid phases, with several reactants in each phase (Reference 8). For this reason, equations that describe this chemistry can be written in many ways, depending on which aspect of the absorption is being emphasized. Moreover, scrubber operating conditions, such as pH, liquid-to-gas ratio, and hold tank residence time can determine which reactions predominate, and whether they occur in the scrubber or in the hold tank (Reference 5).

One set of chemical equations that describe wet scrubbing of SO_2 by lime is shown in Table 5-1. These equations are not meant to be all-inclusive for the reasons given in the preceding paragraph. These equations can be used to represent the main equilibria in an SO_2 wet-scrubbing system using lime under the following normal operating conditions:

Absorbent slurry liquor pH = between 7 and 9 at the scrubber inlet and between 4.5 and 5.5 at the scrubber outlet

Stoichiometric ratio (moles of lime added per mole of SO_2 absorbed) = 1.0 to 1.2

Table 5-1

MAJOR CHEMICAL REACTIONS INVOLVED IN LIME SCRUBBING OF SO_2

Reactions in the Absorber

Absorption

$$SO_2\ (\text{gas}) \rightleftharpoons SO_2\ (\text{aqueous}) \tag{1}$$

$$CO_2\ (\text{gas}) \rightleftharpoons CO_2\ (\text{aqueous}) \rightleftharpoons H_2CO_3 \tag{2}$$

Neutralization

$$SO_3^{=} + H_2CO_3 + H_2O \rightleftharpoons HSO_3^{-} + HCO_3^{-} \tag{3}$$

$$SO_3^{=} + SO_2\ (\text{aqueous}) + H_2O \rightleftharpoons 2HSO_3^{-} \tag{4}$$

$$CaSO_3\ (\text{solid}) + SO_2\ (\text{aqueous}) + H_2O \rightleftharpoons Ca^{++} + 2HSO_3^{-} \tag{5}$$

$$CaCO_3\ (\text{solid}) + 2SO_2\ (\text{aqueous}) + 2H_2O \rightleftharpoons Ca^{++} + 2HSO_3^{-} + H_2CO_3 \tag{6}$$

$$Ca(OH)_2(\text{solid}) + 2SO_2\ (\text{aqueous}) \rightleftharpoons Ca^{++} + 2HSO_3^{-} \tag{7}$$

Oxidation

$$HSO_3^{-} + 1/2O_2 \rightleftharpoons SO_4^{=} + H^{+} \tag{8}$$

Precipitation

$$Ca^{++} + (1-x)SO_3^{=} + (x)SO_4^{=} + 1/2H_2O \rightleftharpoons Ca(SO_3)_{1-x}(SO_4)_x \cdot 1/2H_2O\ (\text{solid}) \tag{9}$$

Reactions in the Hold Tank

Dissolution

$$Ca(OH)_2\ (\text{solid}) + 2HSO_3^{-} \rightleftharpoons Ca^{++} + 2SO_3^{=} + 2H_2O \tag{10}$$

$$Ca(OH)_2\ (\text{solid}) \rightleftharpoons Ca^{++} + 2OH^{-} \tag{11}$$

Oxidation

$$SO_3^{=} + 1/2O_2 \rightleftharpoons SO_4^{=} \tag{12}$$

Precipitation

$$Ca^{++} + SO_4^{=} + 2H_2O \rightleftharpoons CaSO_4.\ 2H_2O\ (\text{solid}) \tag{13}$$

$$Ca^{++} + (1-x)SO_3^{=} + (x)SO_4^{=} + 1/2H_2O \rightleftharpoons Ca(SO_3)_{1-x}\ (SO_4)_x \cdot 1/2H_2O\ (\text{solid}) \tag{14}$$

$$Ca^{++} + HCO_3^{-} + OH^{-} \rightleftharpoons CaCO_3\ (\text{solid}) + H_2O \tag{15}$$

5.1.1 Reactions in the Absorber

The major chemical reactions that occur in the absorber include:

- Absorption and hydration of SO_2 and CO_2
- Neutralization of aqueous alkaline species (such as HCO_3^- and $SO_3^=$) by hydrated SO_2 (aqueous SO_2)* and protons (H^+)
- Dissolution of solid calcium sulfite ($CaSO_3$), calcium carbonate ($CaCO_3$), and calcium hydroxide ($Ca(OH)_2$)
- Oxidation of sulfite species to sulfate in the liquid phase

Absorption of SO_2 and CO_2 in the lime system is governed by gas-liquid equilibria between the SO_2 and CO_2 and the recirculated slurry. If the slurry does not contain alkaline species (defined as any species that is a base to aqueous SO_2), the slurry rapidly becomes saturated with respect to SO_2 and absorption is limited.

The CO_2 that is absorbed reacts with alkaline species (such as $SO_3^=$) to produce bicarbonate ions (HCO_3^-). The HCO_3^- ions may also aid SO_2 neutralization, however, this is not shown here in favor of the net reaction, which is precipitation of $CaCO_3$ in the hold tank and ultimate disposal in the solid waste.

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* The use of the chemical formula H_2SO_3 is avoided here because there seems to be no strong evidence of its existence (Reference 9).

Neutralization of the absorbed SO_2 by aqueous alkaline species is essentially instantaneous (Reference 10). Replenishment of the aqueous alkaline species is necessary to prevent eventual saturation with SO_2. This replenishment occurs when solid $CaSO_3$, $CaCO_3$, $Ca(OH)_2$, or all three dissolve in the tower (and in the hold tank -- see below). The dissolution rate of these solids is a function of the solids concentrations, the particle size distribution of the solids, and scrubber operating conditions, including liquid-to-gas ratio, holdup time in the scrubber, and slurry liquor pH (References 3 and 5).

SO_2 absorption is accompanied by oxidation of the sulfite species to sulfate. Although oxidation at Shawnee continues to be the subject of study, some general statements can be made (Reference 11):

- There is no clear trend as to the effect of pH on sulfite oxidation in lime or limestone SO_2 scrubbing at Shawnee
- Most sulfite oxidation at Shawnee occurs in the absorber and possibly the downcomer
- Slurry liquor composition can affect oxidation at Shawnee. An increase in total dissolved solids lowers solubility of oxygen, which decreases oxidation. However, increased dissolved solids may increase oxidation by increasing the sulfite concentration or by decreasing the average droplet size inside the absorber, or both. (These effects are discussed in Subsection 5.3)
- Catalysts may affect sulfite oxidation. Potential oxidation catalysts are introduced from the flue gas (NO, NO_2), fly ash (metal oxides), lime (metal oxides), makeup water (metal ions), and from equipment erosion or corrosion products (Fe, Cr, Mn, and Cu compounds). There are no independent Shawnee data to support the possibilitly of oxidation catalysis

5.1.2 Reactions in the Hold Tank

The primary chemical reactions that occur in the hold tank include:

- Dissolution of lime
- Precipitation of reaction products, including $CaSO_4 \cdot 2H_2O$, a solid solution of $CaSO_4$ in $CaSO_3 \cdot 1/2H_2O$, and $CaCO_3$

The extent to which these reactions occur in the hold tank depends on the hold tank residence time, the number of hold tanks, pH, stoichiometry, and liquid-to-gas ratio. Under normal operating conditions, dissolution of lime goes to near 100 percent completion. Dissolution of lime raises the liquor pH and the Ca^{++} concentration, which results in precipitation of $CaSO_3$ solids.

Precipitation of $CaSO_3$ goes to completion in accordance with the solubility product, Ksp, which is taken here to be equal to (Reference 12):

$$Ksp = a_{Ca^{++}} \cdot a_{SO_3^{=}} = 4.5 \times 10^{-7} \text{ (mole/liter)}^{-2} \text{ at } 50^{\circ}C$$

where $a_{Ca^{++}}$ and $a_{SO_3^{=}}$ are calcium ion and sulfite ion activities, respectively

Calcium sulfate ($CaSO_4$) precipitates as gypsum (Equation 13, Table 5-1) or as a solid solution in $CaSO_3$ (Equation 14, Table 5-1). Up to 12 to 15 mole percent sulfate can be included in solid solution within the calcium sulfite. Thus, if sulfite oxidation is limited to less than or equal to 12 to 15 percent (Reference 13), absorber operation free of gypsum solids (and hence no gypsum scale) is possible. This mode of operating is frequently observed at Shawnee and at the EPA laboratory in Research Triangle Park, North Carolina (Reference 3 and 14).

If sulfite oxidation is greater than 12 to 15 percent, operation free of gypsum scaling is still possible even though gypsum solids are present. If gypsum saturation* is limited throughout the absorption system to less than 130 to 140 percent, no new gypsum crystals will form on scrubber surfaces and hence, there will be no scaling (Reference 14).

Precipitation of $CaCO_3$ in the hold tank is shown by Equation 15 in Table 5-1. Although $CaCO_3$ aids in the removal of SO_2 in the absorber, it is the main solid waste product that limits lime utilization in this system. Lime (or limestone) utilization is defined as:

Percent Utilization = 100 x TS/TCa = 100/stoichiometric ratio

where TS = total sulfur in the product slurry, moles

TCa = total calcium in the product slurry, moles

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* Percent gypsum saturation = $a_{Ca^{++}} \cdot a_{SO_4^=}$ /K'sp where, for gypsum, K'sp = 2.2×10^{-5} $(mole/liter)^{-2}$ at 50° C and $a_{Ca^{++}}$, $a_{SO_4^=}$ = activities of calcium and sulfate ions.

The concentration of calcium and sulfur in the slurry liquor is normally negligible, so the calcium and sulfur concentrations in the slurry solids are used as a measure of percent utilization.

Not only $CaCO_3$ but any calcium-containing waste product that does not also contain sulfur reduces lime utilization. For example, "dead-burned" lime could be unreactive in the lime system and become part of the product solids.

The calcium sulfite product is shown in Table 5-1 as a solid solution $(Ca(SO_3))_{1-x} (SO_4)_x \cdot 1/2H_2O$, where x ranges up to about 0.12), because it is assumed that if any sulfate ($SO_4^=$) is present in the slurry, some of it will be present in the solid solution with calcium sulfite. There should not be any pure calcium sulfite produced in these systems if oxidation is not zero.

5.2 SCRUBBING WITH LIMESTONE

The overall reaction of limestone with SO_2 may be represented by:

$$CaCO_3 + SO_2 \rightarrow CaSO_3 + CO_2 \qquad (5.2)$$

One mole of limestone reacts with one mole of SO_2 to produce one mole of calcium sulfite and one mole of carbon dioxide, according to this equation. Actually, like lime scrubbing chemistry of SO_2, the chemistry of limestone scrubbing of SO_2 is complex.

Table 5-2 contains equations that represent the major chemical reactions that occur during wet scrubbing of SO_2 with limestone slurries under normal operating conditions. These conditions are:

Absorbent slurry liquor pH = between 5.0 and 6.0 at the scrubber inlet and between 4.5 and 5.5 at the scrubber outlet

Stoichiometric ratio (moles of limestone added per mole of SO_2 absorbed) = 1.1 to 1.6

These equations are not meant to be all inclusive, for the same reasons discussed in Section 5.1.

5.2.1 Reactions in the Absorber

SO_2 reacts with limestone in the absorber to produce Ca^{++} and HSO_3^- in the liquor, and to precipitate calcium sulfite. As in lime scrubbing, most sulfite oxidation probably occurs in the absorber. Unlike lime scrubbing, in limestone scrubbing there is considerable carbon dioxide desorption in the absorber (as well as in the hold tank).

Table 5-2

MAJOR CHEMICAL REACTIONS INVOLVED IN LIMESTONE SCRUBBING OF SO_2

Reactions in the Absorber

Absorption

$$SO_2\,(\text{gas}) \rightleftharpoons SO_2\,(\text{aqueous}) \tag{1}$$

$$CO_2\,(\text{gas}) \rightleftharpoons CO_2\,(\text{aqueous}) \rightleftharpoons H_2CO_3 \tag{2}$$

Desorption

$$HCO_3^- + SO_2\,(\text{aqueous}) + H_2O \rightleftharpoons H_2CO_3 + HSO_3^- \tag{3}$$

$$H_2CO_3 \rightleftharpoons CO_2\,(\text{gas}) + H_2O \tag{4}$$

Neutralization

$$HCO_3^- + SO_2\,(\text{aqueous}) + H_2O \rightleftharpoons H_2CO_3 + HSO_3^- \tag{5}$$

$$SO_3^{=} + SO_2\,(\text{aqueous}) + H_2O \rightleftharpoons 2HSO_3^- \tag{6}$$

$$CaCO_3\,(\text{solid}) + 2SO_2\,(\text{aqueous}) + 2H_2O \rightleftharpoons Ca^{++} + 2HSO_3^- + H_2CO_3 \tag{7}$$

Oxidation

$$HSO_3^- + 1/2O_2 \rightleftharpoons SO_4^{=} + H^+ \tag{8}$$

Precipitation

$$Ca^{++} + (1-x)SO_3^{=} + xSO_4^{=} + 1/2\,H_2O \rightleftharpoons Ca(SO_3)_{1-x}(SO_4)_x \cdot 1/2\,H_2O(\text{solid}) \tag{9}$$

Reactions in the Hold Tank

Dissolution and Desorption

$$CaCO_3\,(\text{solid}) + HSO_3^- \rightleftharpoons Ca^{++} + SO_3^{=} + HCO_3^- \tag{10}$$

$$HCO_3^- + HSO_3^- \rightleftharpoons H_2CO_3 + SO_3^{=} \tag{11}$$

$$H_2CO_3 \rightleftharpoons CO_2\,(\text{aqueous}) \rightleftharpoons CO_2\,(\text{gas}) \tag{12}$$

Oxidation

$$HSO_3^- + 1/2O_2 \rightleftharpoons SO_4^{=} + H^+ \tag{13}$$

Precipitation

$$Ca^{++} + SO_4^{=} + 2H_2O \rightleftharpoons CaSO_4 \cdot 2H_2O\,(\text{solid}) \tag{14}$$

$$Ca^{++} + (1-x)SO_3^{=} + (x)SO_4^{=} + 1/2H_2O \rightleftharpoons Ca(SO_3)_{1-x}(SO_4)_x \cdot 1/2H_2O\,(\text{solid}) \tag{15}$$

5.2.2 Reactions in the Hold Tank

Limestone also dissolves in the hold tank, causing calcium sulfite (as a solid solution with calcium sulfate) to precipitate. Gypsum also precipitates in the hold tank if the gypsum saturation is greater than 100 percent (Reference 4).

5.2.3 Effect of High Stoichiometry

Stoichiometry is an important controllable variable in limestone scrubbing of SO_2. At high stoichiometry where the moles of $CaCO_3$ added per mole of SO_2 absorbed is greater than about 1.3, $CaCO_3$ dissolution occurs primarily in the absorber (Equation 7, Table 5-2 and Reference 5). For every mole of SO_2 absorbed, 1/2 mole of Ca^{++} is released into the liquor. The Ca^{++} can precipitate in the hold tank or in the scrubber as $CaSO_3$ (as a solid solution with calcium sulfate) or $CaSO_4$.

5.2.4 Effect of Low Stoichiometry

At low stoichiometry, (where the moles of $CaCO_3$ added per mole of SO_2 absorbed are less than or equal to 1.1), $CaSO_3$ dissolution in the scrubber may occur, as in the lime system, and contribute to SO_2 removal. The equation is (Reference 5):

$$CaSO_3 + SO_2 + H_2O \rightleftharpoons Ca^{++} + 2HSO_3^-$$

According to this equation, twice as much Ca^{++} is released per mole of SO_2 absorbed by the reaction of SO_2 with $CaSO_3$ than by the reaction of SO_2 with $CaCO_3$. Therefore, slurry leaving the scrubber will have more dissolved Ca^{++} in it at low stoichiometry than at high stoichiometry, as long as Ca^{++} precipitation in the absorber as gypsum does not occur fast enough to reduce the Ca^{++} concentration to its equilibrium value.

5.2.5 Effect of Forced Oxidation*

Since $CaSO_3$ dissolution can be an important scrubbing mechanism at low stoichiometry in the limestone system (and at normal stoichiometry in the lime system), forced oxidation of $CaSO_3$ to $CaSO_4$ (by sparging the hold tank with air, for example), which eliminates this scrubbing mechanism, could result in low SO_2 removal efficiencies. Forced oxidation has been investigated at Research Triangle Park. Preliminary results indicate that CO_2 stripping caused by the air sparging enhances limestone dissolution, and hence nullifies any possible adverse effects on SO_2 removal caused by forced oxidation.

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* Forced oxidation represents any means external to the scrubber by which essentially all of the $CaSO_3$ is oxidized to gypsum.

5.3 EFFECT OF MAGNESIUM ON AQUEOUS ALKALINITY

In both lime and limestone scrubbing of SO_2, aqueous alkaline species (those ions that are a base to aqueous SO_2), such as HCO_3^- and $SO_3^=$ account for the SO_2 removal achieved. If Ca^{++} is the only cation present, the HCO_3^- and $SO_3^=$ concentrations are fixed by the pH and the Ca^{++} concentration (or more strictly speaking, the Ca^{++} activity) according to the equilibria below, which are written to show the loss of alkaline species as the forward reaction.

$$HCO_3^- + H^+ \rightleftharpoons H_2CO_3 \qquad (5.3)$$

$$Ca^{++} + SO_3^= \rightleftharpoons CaSO_{3(s)} \qquad (5.4)$$

$$Ca^{++} + HCO_3^- \rightleftharpoons CaCO_{3(s)} + H^+ \qquad (5.5)$$

To increase the concentration of alkaline species, a cation that forms a soluble sulfate or sulfite compound must be introduced. In addition, the cations must be introduced in a soluble compound in combination with sulfate or sulfite or with anions that are alkaline to SO_2. Chloride is not alkaline to SO_2. These criteria are summarized below:

- The cations must be introduced into the liquor with sulfite or sulfate as the anion, or the anion must be a base to SO_2

  Acceptable: $MgSO_4$, Na_2CO_3, NaOH, MgO, NH_3
  Unacceptable: $MgCl_2$, NaCl, $CaCl_2$

- The cations and their sulfite and sulfate compounds must be soluble within the scrubbing system

  Good: $MgSO_4$, Na_2SO_4, $(NH_4)_2SO_4$
  Poor: Al_2O_3, Fe_2O_3

Examples are shown below to illustrate how some substances have no effect on the concentration of alkaline species and how other substances increase the concentration of alkaline species.

No Major Effect on Alkaline Species Concentration

$$MgCl_2(s) \rightarrow Mg^{++} + 2Cl^- \tag{5.6}$$

$$NaCl(s) \rightarrow Na^+ + Cl^- \tag{5.7}$$

Increases Alkaline Species Concentration

$$MgO(s) + H_2O \rightarrow Mg^{++} + 2OH^- \tag{5.8a}$$

$$Mg^{++} + SO_3^= \rightleftharpoons MgSO_3^o \tag{5.8b}$$

$$SO_2 + 2OH^- \rightarrow SO_3^= + H_2O \tag{5.8c}$$

$$MgSO_4(s) \rightleftharpoons Mg^{++} + SO_4^= \tag{5.9a}$$

$$SO_4^= + CaSO_3(s) \rightleftharpoons CaSO_4(s) + SO_3^= \tag{5.9b}$$

$$Na_2CO_3(s) \rightarrow 2Na^+ + CO_3^= \tag{5.10a}$$

$$CO_3^= + SO_2 \rightleftharpoons CO_2 + SO_3^= \tag{5.10b}$$

$$Na_2SO_4(s) \rightarrow 2Na^+ + SO_4^= \tag{5.11a}$$

$$SO_4^= + CaSO_3(s) \rightleftharpoons CaSO_4(s) + SO_3^= \tag{5.11b}$$

In Equations 5.8a through 5.11b, the alkaline species produced by adding magnesium and sodium compounds that meet the above criteria are OH^-, $MgSO_3^o$, $SO_3^=$, and $CO_3^=$. Chloride (Cl^-) is not an alkaline species; when $MgCl_2$ and NaCl are added there is no major increase in the concentration of alkaline species.

5.3.1 Effect of Chloride on Magnesium Activity

It has become common practice to use the concentration of "effective" cations as a controllable variable, rather than the concentration of alkaline anions. "Effective" cation concentration can be defined as:

$$\left(\sum_i n_i\,[c_i]\right)_{\text{effective}} = \left(\sum_i n_i\,[c_i]\right)_{\text{total}} - \left(\sum_j n_j\,[a_j]\right)_{\text{total}}$$

where brackets signify concentration, in g-moles/ liter, n_i and n_j are the number of equivalents per mole of the cations and the anions, $[c_i]$ are the concentrations of the cations in the liquor, and $[a_j]$ are the concentrations of inactive anions. Inactive anions are those anions other than $SO_4^=$, $SO_3^=$, HCO_3^-, $CO_3^=$, and OH^-. In most lime/limestone systems, chloride ion is the only inactive anion in significant concentrations.

If magnesium is the only added cation (added as MgO or $MgSO_4$, for example) and chloride is the only inactive anion, the equation simplifies to:

$$2\,[Mg^{++}]_{\text{effective}} = 2\,[Mg^{++}]_{\text{total}} - [Cl^-]$$

when $[Cl^-] \geq 2\,[Mg^{++}]_{total}$, then $[Mg^{++}]_{effective} = 0$

If the Mg^{++} and Cl^- concentrations are expressed in ppm, the equations become:

$$\begin{aligned}(Mg^{++})_{effective} &= (Mg^{++})_{total} - (Cl^-)/2.92 \\ &= 0 \text{ for } (Mg^{++})_{total} \leq (Cl^-)/2.92\end{aligned}$$

5.3.2 Effect of Chloride on pH and SO_2 Removal

At a constant stoichiometric ratio (i.e., constant moles of limestone or lime added per mole of SO_2 absorbed), increasing the chloride concentration can reduce the equilibrium pH, as well as reduce the liquor alkalinity (the effective magnesium ion concentration). One explanation for this effect is the following. As the Cl^- concentration increases, (by absorption of HCl from the flue gas for example), the Ca^{++} concentration increases (Reference 5). The Ca^{++} concentration is related to the $CO_3^=$ concentration according to the equation:

$$(Ca^{++})\ (CO_3^=) = K_{CaCO_3} = \text{constant} \qquad (5.12a)$$

The $CO_3^=$ concentration is related to the H^+ concentration (at constant

CO_2 and SO_2 partial pressure) by the equation:

$$(H^+)^2 (CO_3^=) = K_{H_2CO_3} \times p_{CO_2} = \text{constant} \qquad (5.12b)$$

So, as Ca^{++} concentration increases, $CO_3^=$ concentration decreases (to keep their product constant). The H^+ concentration must then increase (that is, the pH must decrease) in accordance with Equation 5.12b.

To raise the pH again to where it would be without the chloride, additional limestone (or lime) is required. At a constant scrubber inlet liquor pH, SO_2 removal should therefore increase with increasing chloride concentration. This increased SO_2 removal is not directly caused by the Cl^- concentration, but is rather a result of the higher limestone stoichiometry when chloride is present at the same pH.

5.3.3 Effect of Added Effective Cations on $CaSO_3$ and $CaCO_3$ Equilibria

Adding effective cations to the slurry can affect SO_2 removal through liquor equilibria. When the concentration of effective cations increases, the concentration of sulfate ions increases. For given levels of $CaSO_4$, $CaSO_3$, and $CaCO_3$ saturation, $SO_4^=$ influences soluble alkali via the following equilibria (Reference 15):

$$CaSO_3(s) + SO_4^{=} \rightleftharpoons CaSO_4(s) + SO_3^{=} \qquad (5.13)$$

$$CaCO_3(s) + CO_2 + H_2O + SO_4^{=} \rightleftharpoons CaSO_4(s) + 2HCO_3^{-} \qquad (5.14)$$

The concentrations of alkaline species $SO_3^{=}$ and HCO_3^{-} are thus proportional to the sulfate concentration by the following equations:

$$[SO_3^{=}] \propto [SO_4^{=}](\gamma_{CaSO_3} / \gamma_{CaSO_4})$$

$$[HCO_3^{-}] \propto [SO_4^{=}](pCO_2)(\gamma_{CaCO_3} / \gamma_{CaSO_4})$$

where:

γ_{CaSO_3}, γ_{CaSO_4}, γ_{CaCO_3} = relative saturation of the species shown

pCO_2 = partial pressure of CO_2 over the solution

In summary, effective magnesium (and presumably other cations) can increase the concentration of sulfate in solution, thereby increasing the concentration of aqueous alkali, and subsequently increasing SO_2 removal at equivalent operating conditions. Alternatively, effective magnesium can be used to increase alkali utilization at equivalent SO_2 removal (Reference 3).

5.3.4 Effect of pH on Liquor Alkalinity

At the normal operating pH range of 7.0 to 8.0 in lime systems, the liquor sulfite species is predominately $SO_3^=$, and not HSO_3^-, because of the high pH. The distribution of SO_2(aqueous), HSO_3^-, and $SO_3^=$, as well as the distribution of H_2CO_3, HCO_3^-, and $CO_3^=$ in solution as a function of pH are shown in Figure 5-1.

In the limestone system, the sulfite is in the bisulfite form because of the low operating pH range of 4.5 to 6.0 in the scrubber. However, the total sulfite concentration is about the same as in the lime system. The following equilibrium illustrates this:

$$CaSO_3(s) \rightleftharpoons Ca^{++} + SO_3^=$$

Sulfite concentration is dependent on Ca^{++} concentration and independent of pH according to this equilibrium.

Adding magnesium sulfate increases sulfite concentration (as the ion pair $MgSO_3^o$) via a pH independent equilibrium:

$$Mg^{++} + SO_4^= + CaSO_3(s) \rightleftharpoons MgSO_3^o + CaSO_4(s)$$

This effect of magnesium is illustrated by using the Bechtel Modified Radian Equilibrium Computer Program (Reference 12). At a given effective Mg^{++} concentration, the aqueous alkalinity due to sulfite species is calculated to be approximately the same for lime slurry as limestone slurry, as is shown in Table 5-3. At 6000 ppm effective

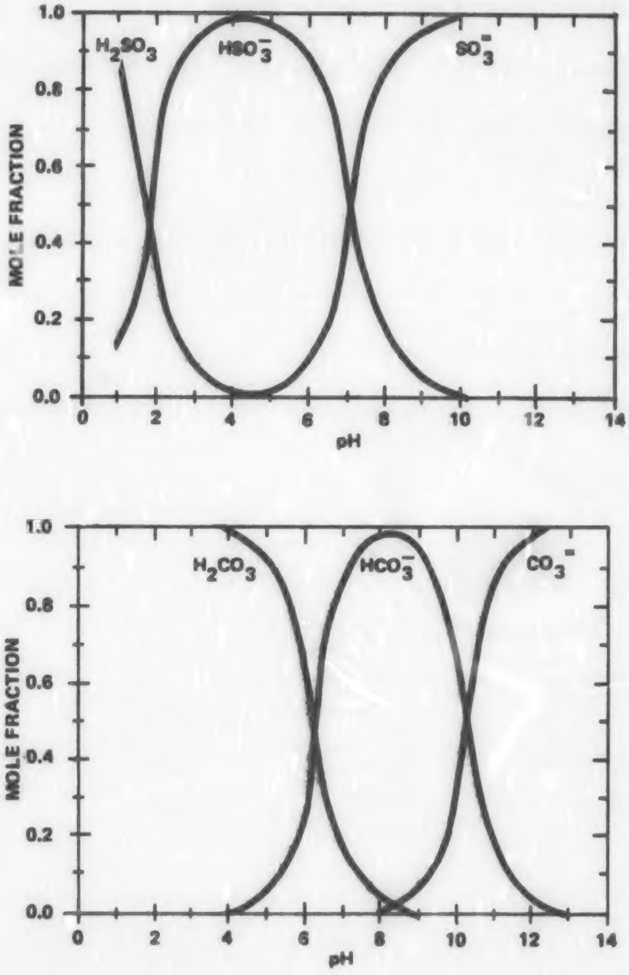

Figure 5-1. Bisulfite-Sulfite Distribution and Bicarbonate Distribution as a Function of pH

Table 5-3

EFFECT OF MAGNESIUM ON AQUEOUS ALKALINITY

Alkali	Mg^{++}, ppm	pH	P_{CO_2}, atm	Aqueous Alkalinity,[a] mmole/l
Limestone	0	5.2	0.12	1.66
Limestone	0	5.5	0.12	1.68
Limestone	0	5.8	0.12	1.69
Limestone	3000	5.2	0.12	5.89
Limestone	3000	5.5	0.12	6.21
Limestone	3000	5.8	0.12	6.41
Limestone	6000	5.2	0.12	10.86
Limestone	6000	5.5	0.12	11.27
Limestone	6000	5.8	0.12	11.49
Limestone	9000	5.2	0.12	16.24
Limestone	9000	5.5	0.12	16.78
Limestone	9000	5.8	0.12	17.04
Lime	6000	6.9	0.0003	11.78
Lime	6000	7.4	0.0003	11.79
Lime	6000	7.9	0.0003	11.78

Note: The liquor is saturated with $CaSO_3$, and $CaSO_4$ (gypsum) but not with $CaCO_3$.
Liquor temperature: 50° C
No chloride ions are present.

(a) Figured as $[SO_3^=] + [CaSO_3] + [MgSO_3]$. The concentration of HCO_3^- is negligible under these conditions.

magnesium, the aqueous alkalinity (or $[SO_3^=]_{total}$) defined as the sum of the concentrations of sulfite, calcium sulfite ion pair, and magnesium sulfite ion pair) is 11.49 mmole/liter at pH 5.8 in the limestone system, and 11.78 at pH 7.9 in the lime system.

5.3.5 Effect of Magnesium Addition at Shawnee - An Illustration

The effect of magnesium on the total sulfite concentration in lime slurry at Shawnee can be seen in Figure 5-2. $[SO_3^=]_{total}$ is plotted against $[Mg^{++}]/[Ca^{++}]$ to illustrate the relationships:

$$
\begin{aligned}
[SO_3^=] &= K_1/[CaSO_3]/[Ca^{++}] = K_1'/[Ca^{++}] \\
[MgSO_3^o] &= [SO_3^=][Mg^{++}]/K_2 \\
&= K_1' \ [Mg^{++}]/K_2[Ca^{++}]
\end{aligned}
$$

where $[CaSO_3^o]$ is assumed to be constant, and K_1 and K_2 are equilibrium constants.

The observed effect of the aqueous alkalinity $[SO_3^=]_{total}$ on SO_2 removal is shown in Figure 5-3. At 3000 ppm SO_2 (inlet), the removal predicted by Figures 5-2 and 5-3 is 68 percent at 240 ppm sulfite ($Mg^{++}_{effective}$ = 2000 ppm, Mg/Ca = 5) and 91 percent at 1200 ppm sulfite ($Mg^{++}_{effective}$ = 2000 ppm, Mg/Ca = 40). The Mg/Ca ratio (wt. percent Mg^{++} in the liquor/wt. percent Ca^{++} in the liquor) is affected primarily by gypsum saturation, which is almost unpre-

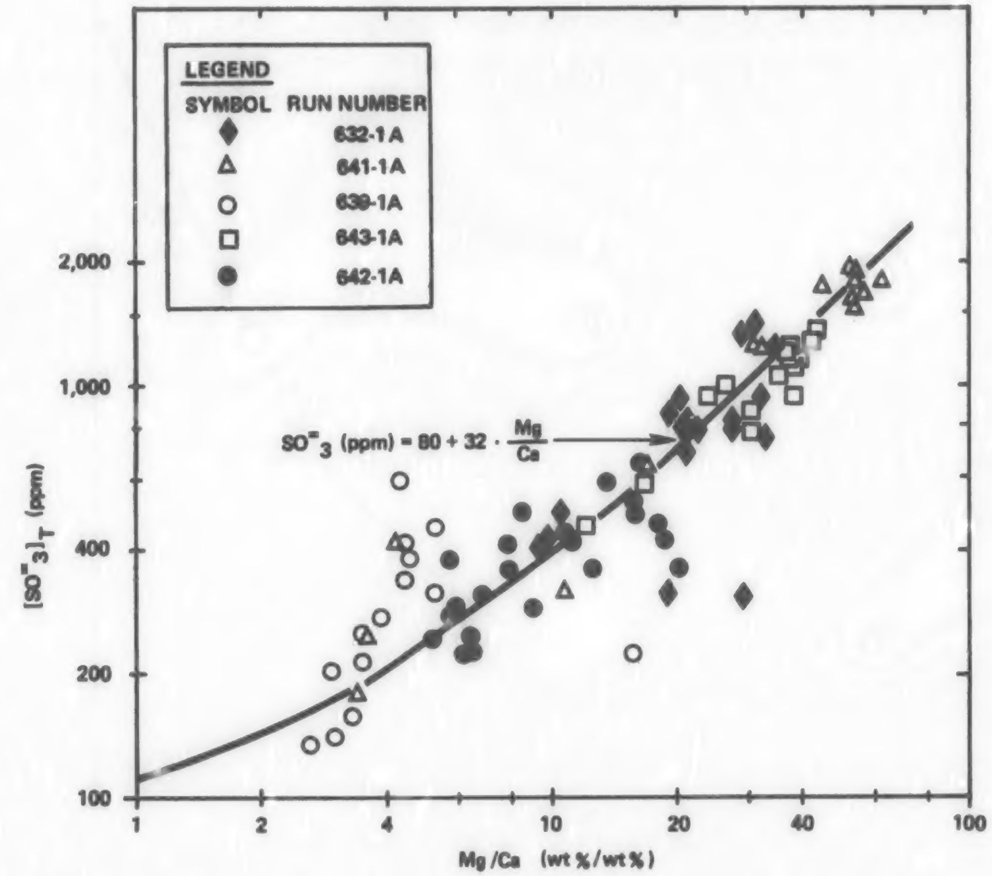

Figure 5-2. Total Sulfite Concentration $[SO_3^=]_T$ in Lime Scrubbing as a function of the ratio of Mg Concentration to Ca Concentration (Mg/Ca)

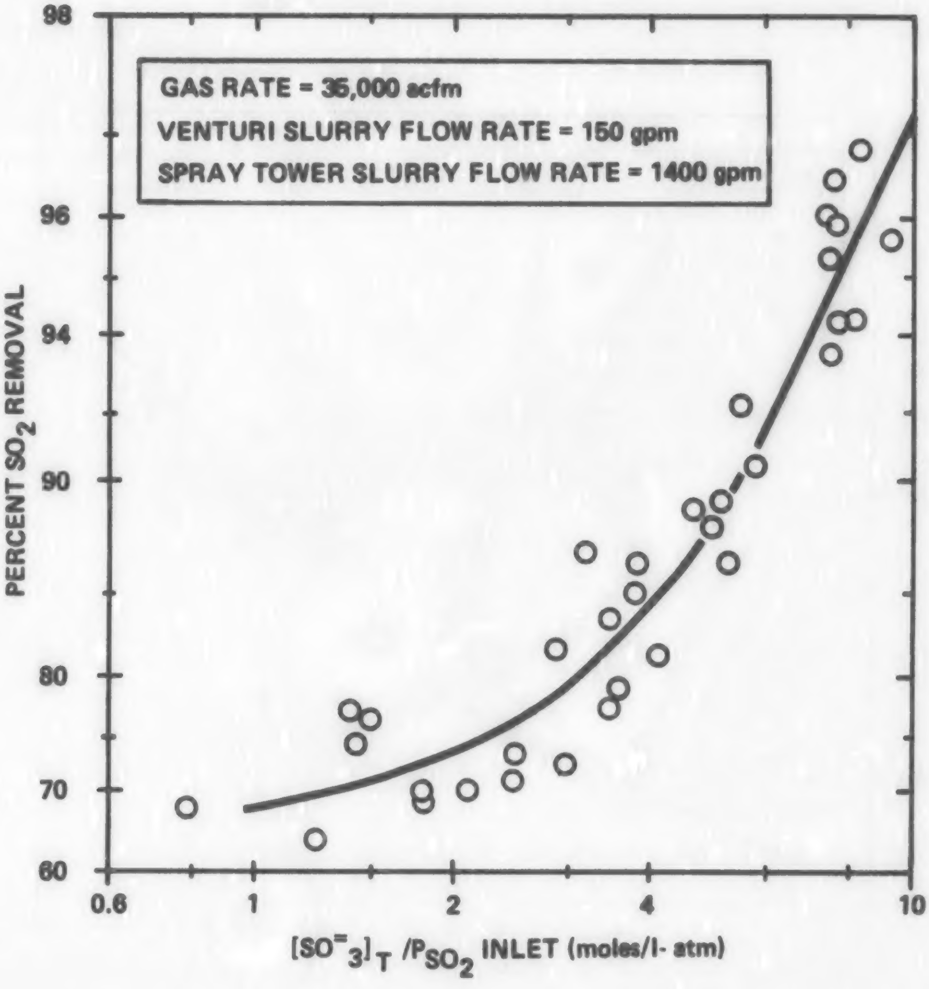

Figure 5-3. Effect of the ratio of Total Sulfite Concentration $[SO_3^=]_T$ to SO_2 Concentration (P_{SO_2}) on SO_2 Removal - Spray Tower with Lime for Runs 632-1A and 641-1A

dictable except that at sulfite oxidations above about 12 to 15 percent the slurry liquor at Shawnee will usually be saturated with respect to gypsum.

5.4 EFFECT OF MAGNESIUM ON SULFITE OXIDATION AND GYPSUM SATURATION

As yet, there is no general understanding of the effect of magnesium on sulfite oxidation and gypsum saturation. One can, however, say that (Reference 11):

- The increase in total dissolved solids introduced by adding magnesium increases the potential for oxygen mass transfer (by decreasing the average droplet size inside the absorber) but decreases oxygen solubility

  As a result, oxidation can either increase (owing to the enhanced oxygen mass transfer) or decrease (owing to the lower oxygen solubility at the high ionic strength), or stay the same (if these two effects cancel each other)

- The sulfite concentration increases when the effective magnesium concentration increases. Oxidation should increase if sulfite ions participate in the rate determining step

- The increase in the concentration of sulfite and sulfate introduced by adding magnesium depresses the Ca^{++} concentration and can cause unexpected gypsum scaling in the absorber

  If because of the addition of magnesium, enough alkalinity is present in the liquor to absorb all of the SO_2, there should be no gypsum saturation increase across the scrubber. However, since Ca^{++} is suppressed by magnesium and will be at a low value in the slurry at the scrubber inlet, if $CaSO_3$ or $CaCO_3$ dissolves in the scrubber, there can be a great increase in gypsum saturation across the scrubber. This can result in unexpected scaling

- Higher effective magnesium increases SO_2 removal. Thus, at a constant oxidation rate, the fraction of SO_2 oxidized should be less when more effective magnesium is present in the slurry because more SO_2 is introduced into the slurry per unit time

Section 6

VENTURI/SPRAY TOWER FACTORIAL TEST RESULTS

From February through April 1976, a series of 133 (6 to 8-hour) limestone, lime, and limestone/MgO factorial tests were conducted on the venturi/spray tower system. Seven lime/MgO factorial tests had previously been made on the venturi/spray tower during November 1974.

The venturi scrubber and the spray tower were tested independently to observe the effect on SO_2 removal of operating at different values of the major operating variables. Correlations of these data are presented in Section 14. The test results are presented in this section.

6.1 TEST DESCRIPTION

The term factorial tests as used here is defined as a specific set of runs of short duration, the operating time for each run being the minimum time to reach and hold steady state for 6 hours with respect to flow rate, SO_2 removal, and liquor (but not solid) composition.

A complete factorial set would include every possible combination of independent variables (e.g., gas rate, liquor rate, effective dissolved magnesium ion concentration) thought to affect the dependent variable (e.g., SO_2 removal). For example, a complete factorial set designed to cover 5 independent variables with 3 operating levels per variable would require 3^5 or 243 tests. Because of time limitations, complete factorial sets were impossible.

The Shawnee tests were designed as partial factorial sets with test conditions picked to obtain the maximum amount of information in the relatively small number of runs possible. Each partial factorial set had at least three specific values for each independent variable.

Several replicate runs were made in each factorial set to determine any time trends in the data. However, practical operating considerations require that some tests be grouped (e.g., high magnesium ion concentration in the slurry liquor). The Shawnee factorial tests were run in an order that represented a compromise between statistical randomness and operating convenience.

6.2 DATA QUALITY

A number of measures were taken to ensure the best possible data from the Shawnee factorial runs. The major problems resulted from the difficulty of maintaining steady state conditions in the flue gas, particularly the inlet SO_2 concentration. This difficulty is inherent in a test facility attached to an operating power station.

To minimize variation in the inlet flue gas SO_2 concentration, coal from only one source (Old Ben No. 24 Mine) was selected to be burned in Boiler No. 10 during the 1976 factorial testing. The inlet SO_2 concentration varied from 2500 to 3000 ppm with this coal. However, during the last half of the limestone/MgO testing the supply of Old Ben No. 24 coal was exhausted, and the inlet SO_2 concentration range increased to 2500 to 3500 ppm with the new coal.

For most of the factorial tests, the coal had an unexpectedly high chloride content; liquor chloride-ion concentrations ranged from 9000 to 15,000 ppm rather than the previously normal range of 2000 to 6000 ppm. These high chloride concentrations may account for the difference in removal observed between the factorial data and earlier long-term test data. The effect of chloride on SO_2 removal is discussed in Sections 5 and 14.

Data values discussed in this section have been averaged for the steady-state operating portion of each test. The steady state period was taken to be that part of the test during which the controlled operating variables (e.g., slurry flow rate, scrubber gas velocity, scrubber inlet liquor pH, dissolved magnesium concentration) and the SO_2 removal were essentially constant.

Also, a number of runs were repeated. These replicate runs showed good agreement. SO_2 removals were within 6 percentage points of each other for each replicate pair.

No attempt was made to monitor scale buildup, corrosion or other essentially long-term phenomena during the factorial runs, as such data would be of doubtful quality from short tests.

6.3 LIMESTONE TESTING

Data from the 42 limestone factorial tests on the venturi scrubber and on the spray tower system are given in Table 6-1.

6.3.1 Venturi Scrubber Limestone Results

Fifteen limestone factorial tests were performed on the venturi scrubber. In these tests no slurry was pumped to the spray tower. Independent variables tested with the venturi limestone system were:

- Gas flow rate
- Slurry recirculation rate
- Scrubber inlet liquor pH
- Venturi pressure drop

Table 6-1

SUMMARY OF LIMESTONE FACTORIAL TESTS ON THE VENTURI/SPRAY TOWER SYSTEM

Run Number	Gas Rate, acfm	Liquor Rate, gpm		ST Gas Vel., ft/sec	L/G, gal/Mcf		Press. Drop, in. H_2O		Scrubber Inlet Liquor pH		Scrubber Outlet Liquor pH	Inlet SO_2 Conc., ppm		Percent SO_2 Removal		No. of Spray Headers Used	Replicate Number
		V	ST		V	ST	V	ST	Range	Avg.		Range	Avg.	Range	Avg.		
VST101	27500	145	0	7.4	6.6	0	2.2	2.0	5.72-5.85	5.78		2920-2960	2933	6- 8	7	0	A
VST102	27500	150	0	7.4	6.8	0	2.4	1.7	5.17-5.29	5.21		2860-2900	2887	0- 3	2	0	
VST103	27500	150	0	7.4	6.8	0	2.2	1.8	5.40-5.52	5.48		2840-2900	2868	0- 2	1	0	
VST104	27500	140	0	7.4	6.3	0	1.8	2.5	5.60-5.77	5.67	4.95	2900-2920	2907	4- 6	5	0	A
VST105	35000	300	0	9.4	10.7	0	8.0	4.3	5.75-5.89	5.81		2900-3000	2950	32-40	35	0	
VST106	20000	600	0	5.4	37.4	0	9.1	1.1	5.75-5.83	5.79		2720-2760	2740	43-43	43	0	B
VST107	35000	600	0	9.4	21.4	0	9.1	4.6	5.73-5.83	5.77		2760-2840	2811	40-45	42	0	
VST108	27500	600	0	7.4	27.2	0	9.0	2.6	5.78-5.88	5.82		2560-2800	2654	47-49	48	0	C
VST109	20000	600	0	5.4	37.4	0	9.1	1.3	5.71-5.79	5.76		2520-2760	2651	46-49	47	0	B
VST110	20000	300	0	5.4	18.7	0	8.0	1.0	5.73-5.77	5.75		2760-2800	2794	31-32	32	0	
VST111	27500	600	0	7.4	27.2	0	6.0	2.5	5.62-5.70	5.67		2720-2880	2800	36-38	37	0	
VST112	27500	600	0	7.4	27.2	0	11.9	2.5	5.49-5.69	5.62		2440-2720	2553	45-47	46	0	
VST113	27500	600	0	7.4	27.2	0	9.0	2.4	5.69-5.78	5.73		2640-2680	2657	41-43	42	0	C
VST114	27500	600	0	7.4	27.2	0	9.1	2.5	5.33-5.60	5.53		2640-2680	2663	32-41	37	0	
VST115	27500	600	0	7.4	27.2	0	8.0	2.5	5.11-5.26	5.20		2740-2840	2780	20-29	25	0	
VST116	35000	145	1125	9.4	5.2	40	4.0	4.0	5.81-5.88	5.84		2480-2600	2543	72-73	72	3(1,3,4)	
VST117	35000	150	750	9.4	5.3	27	2.7	4.0	5.76-5.82	5.80	4.97	2760-2800	2773	54-60	58	2(3,4)	D
VST118	20000	145	1500	5.4	9.0	94	1.1	2.1	5.67-5.83	5.75		3140-3200	3164	86-89	88	4	E
VST119	27500	145	1125	7.4	6.6	51	2.4	2.9	5.62-5.94	5.83		2500-2660	2569	73-78	76	3(1,3,4)	F
VST120	20000	150	1125	5.4	9.3	70	2.3	1.5	5.77-5.81	5.79		2600-2660	2626	77-81	79	3(1,3,4)	
VST121	35000	145	750	9.4	5.2	27	3.1	4.1	5.73-5.85	5.81		2520-2720	2629	57-60	59	2(3,4)	D
VST122	27500	14[illegible]	1500	7.4	6.3	68	1.7	3.2	5.70-5.85	5.81		2840-3000	2920	79-80	80	4	
VST123	35000	14[illegible]	1500	9.4	5.0	53	3.5	4.4	5.67-5.90	5.80		3000-3200	3122	70-77	74	4	
VST124	27500	145	1125	7.4	6.6	51	2.9	2.9	5.72-5.90	5.83		2520-2600	2554	74-80	78	3(1,3,4)	F
VST125	20000	145	750	5.4	9.0	47	1.0	1.8	5.75-5.80	5.78		2680-2840	2771	60-69	68	2(3,4)	
VST126	20000	145	1500	5.4	9.0	94	1.2	1.7	5.77-5.89	5.83		2860-3000	2900	89-91	90	4	E
VST127	27500	145	750	7.4	6.6	34	2.2	3.4	5.78-5.85	5.82	4.90	2600-2680	2633	63-67	65	2(3,4)	H
VST128	27500	145	1125	7.4	6.6	51	1.9	2.4	5.48-5.60	5.54	5.02	2400-2600	2530	66-69	67	3(1,3,4)	
VST129	27500	145	1500	7.4	6.6	68	2.2	3.1	5.44-5.61	5.51		2920-3000	2947	72-75	73	4	
VST130	27500	145	1500	7.4	6.6	68	2.7	2.5	5.04-5.35	5.16		2740-2900	2823	62-71	66	4	G
VST131	27500	145	1125	7.4	6.6	51	2.8	2.0	5.03-5.40	5.17		2600-2680	2648	54-58	56	3(1,3,4)	
VST132	27500	140	1500	7.4	6.3	68	2.2	3.3	5.08-5.30	5.21	5.11	2480-2600	2537	65-70	67	4	G
VST134	27500	145	750	7.4	6.6	34	3.0	2.6	5.74-5.81	5.78	4.98	2680-2760	2717	60-61	60	2(3,4)	H
VST136	27500	145	750	7.4	6.6	34	2.1	2.5	5.98-6.05	6.02	4.98	3000-3040	3020	67-72	69	2(1,2)	
VST137	27500	145	750	7.4	6.6	34	2.0	2.6	5.78-5.85	5.81		2520-2680	2580	62-65	63	2(1,4)	
VST138	27500	140	1125	7.4	6.3	51	2.0	2.9	5.60-5.74	5.68	4.93	3040-3080	3065	65-68	66	4	I
VST139	27500	150	1125	7.4	6.8	51	3.2	2.8	5.72-5.82	5.78		2440-2640	2535	72-74	73	3(1,3,4)	F
VST140	27500	145	1125	7.4	6.6	51	2.2	2.7	5.71-6.02	5.75	5.06	2680-2800	2738	66-71	68	4	I
VST141	27500	150	700	7.4	6.8	35	2.0	2.6	5.81-6.63	5.99		2420-2800	2610	70-73	72	2(3,4)	
VST142	27500	145	750	7.4	6.6	34	2.9	2.6	5.14-5.26	5.20	4.57	2660-2740	2683	42-46	43	2(3,4)	
VST143	27500	145	750	7.4	6.6	34	1.9	2.6	5.44-5.56	5.50	4.84	2320-2640	2480	50-56	52	2(3,4)	
VST144	27500	150	750	7.4	6.8	34	2.0	2.6	5.87-5.91	5.89		2640-2720	2673	69-70	70	2(3,4)	

The effect of scrubber inlet liquor pH on percent SO_2 removal by the venturi scrubber operating with a pressure drop of 9 inches of H_2O and a liquid-to-gas ratio of 27 gal/Mcf is shown in Figure 6-1. The data show an increase in SO_2 removal with increasing pH.

Figure 6-2 illustrates the effects of slurry and gas flow rates on percent SO_2 removal by the venturi scrubber at 9 inches pressure drop and constant scrubber inlet liquor pH. The data indicate that percent removal increases with increasing slurry flow rate but changes only slightly with a change in gas rate. In Figure 6-3 the data are replotted to show the increase in SO_2 removal with increasing liquid-to-gas ratio.

Figure 6-4 shows the effect of pressure drop on SO_2 removal by the venturi scrubber at a liquid-to-gas ratio of 27 gal/Mcf. The data show an increase in percent SO_2 removal with increasing pressure drop. This effect is weaker for lime scrubbing in the venturi at a pH of 8.0 (see Figure 6-11).

6.3.2 Spray Tower Limestone Results

Twenty seven limestone factorial tests were performed on the spray tower. Spray-tower-only runs were made with a minimum pressure drop in the venturi of about 2 inches of H_2O and a minimum slurry

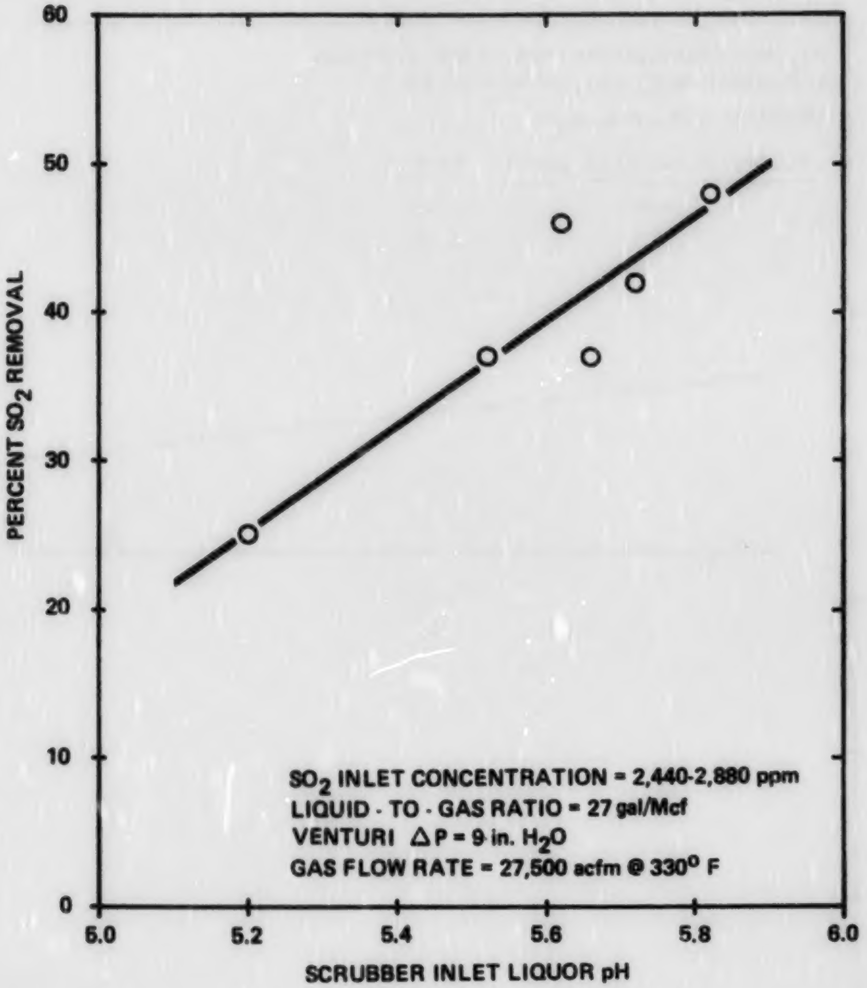

Figure 6-1. Effect of Scrubber Inlet Liquor pH on SO_2 Removal - Venturi Scrubber with Limestone

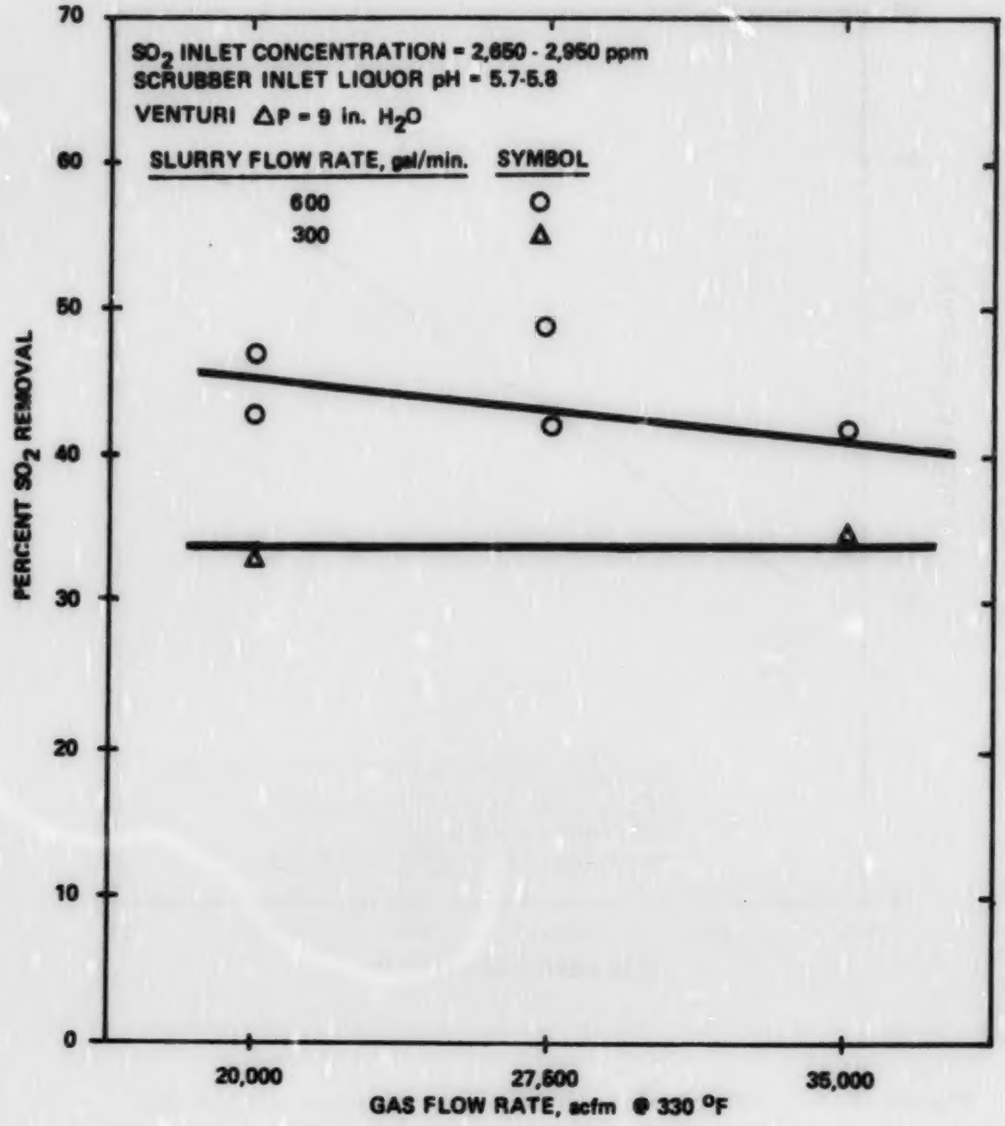

Figure 6-2. Effect of Slurry and Gas Flow Rates on SO_2 Removal - Venturi Scrubber with Limestone

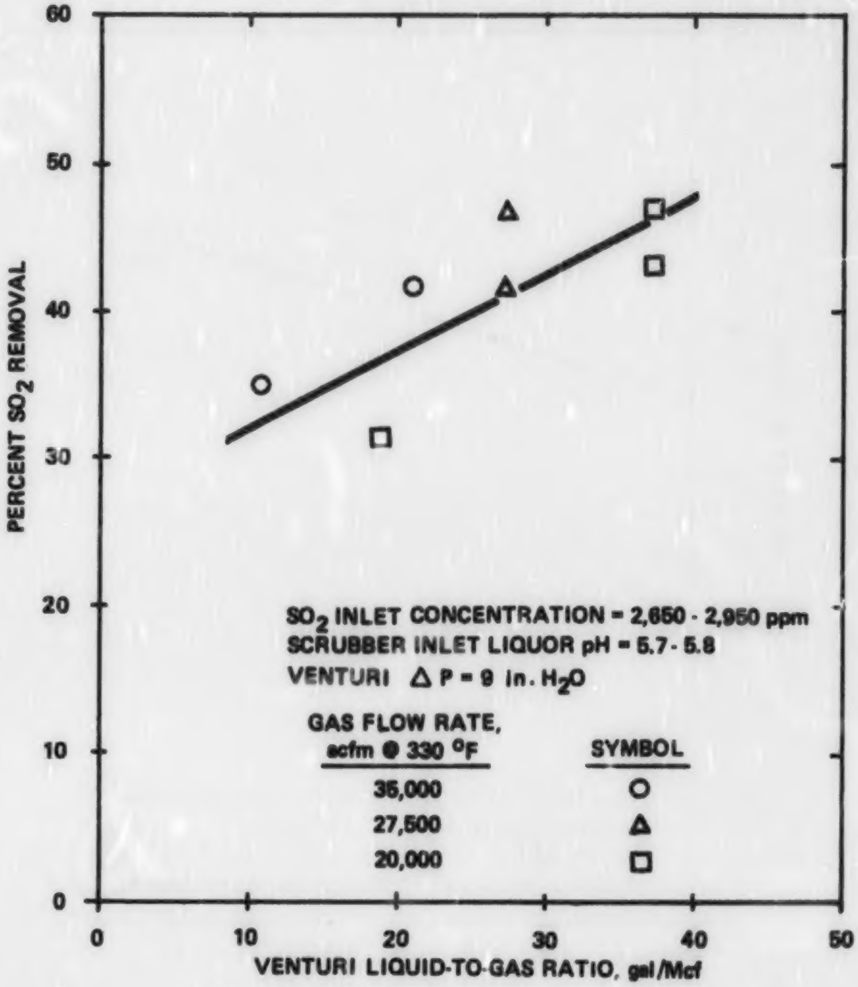

Figure 6-3. Effect of Liquid-to-Gas Ratio and Gas Flow Rate on SO_2 Removal - Venturi Scrubber with Limestone

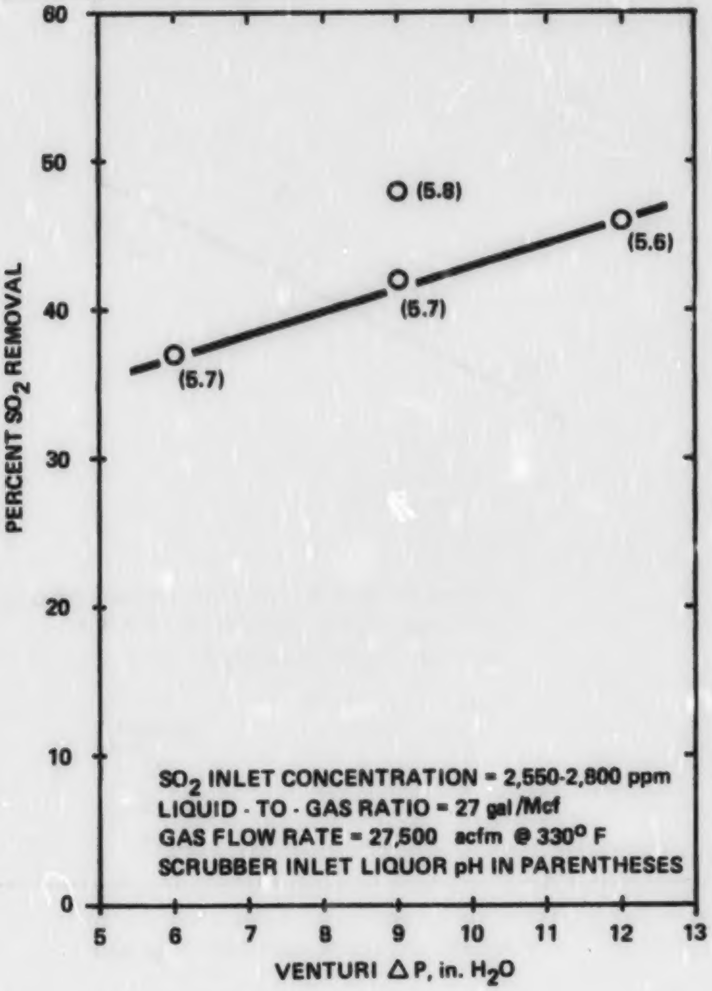

Figure 6-4. Effect of Venturi Pressure Drop on SO_2 Removal - Venturi Scrubber with Limestone

flow rate of about 150 gpm to the venturi to cool the inlet flue gas. At these conditions, SO_2 removal in the venturi was less than 5 percent (see Runs VST-101 through VST-104, Table 6-1). With such low venturi removal, the spray tower removal differs from the total system removal by about 1 percentage point or less. For this reason, the effects of the venturi were neglected in evaluating spray-tower-only runs.

Independent variables tested with the spray tower limestone system were:

- Gas flow rate
- Slurry recirculation rate
- Scrubber inlet liquor pH
- Number of spray headers
- Spray nozzle pressure drop

Figure 6-5 illustrates the effects of scrubber inlet liquor pH and of liquid-to-gas ratio on percent SO_2 removal in the spray tower at a superficial gas velocity of 7.4 ft/sec.* SO_2 removal increases with increasing pH and with increasing liquid-to-gas ratio.

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* Gas velocity is calculated at scrubber temperature (nominally 125 °F). The spray tower cross-sectional area is 50 square feet.

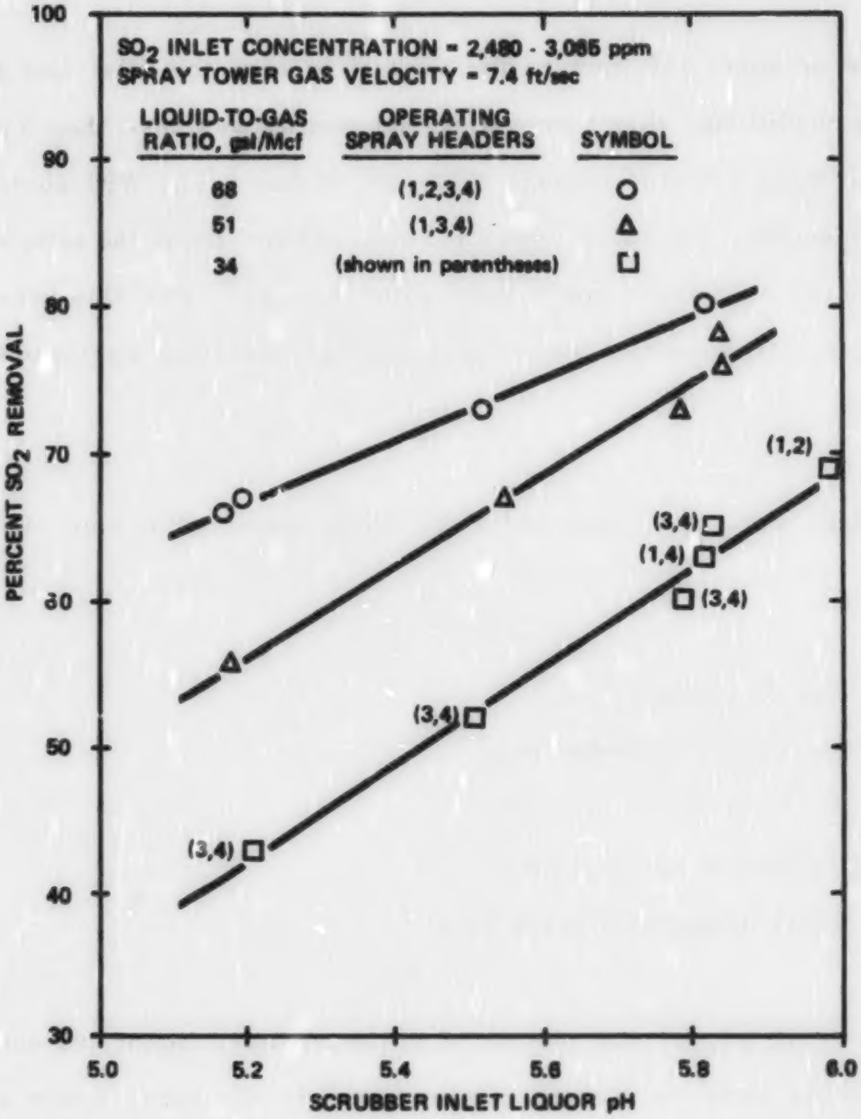

Figure 6-5. Effect of Scrubber Inlet Liquor pH and Liquid-to-Gas Ratio on SO_2 Removal - Spray Tower with Limestone

Figure 6-6 shows the effects on percent SO_2 removal when gas rate and slurry rate are varied independently. SO_2 removal is enhanced by increasing slurry rate or decreasing gas rate. (This compares with a slight increase in removal with increasing gas rate in the TCA. See Figure 9-2). It should be noted that liquid-to-gas ratio is changed when either slurry or gas rate is changed independently. The drop in SO_2 removal as gas is increased reflects the resulting decrease in liquid-to-gas ratio.

Figure 6-7 shows the increase in percent SO_2 removal with liquid-to-gas ratio at a scrubber inlet liquor pH of 5.8 and a consant superficial gas velocity of 7.4 ft/sec. Also shown is the effect of nozzle pressure drop and the number of headers. At a liquid-to-gas ratio of 50 gal/Mcf, SO_2 removal increased by about 8 percentage points when the nozzle pressure drop was increased from 7.9 to 14.3 psi by decreasing the number of spray headers from four (1, 2, 3, and 4 counting from the bottom up) to three (1, 3, and 4).

6.4 LIME TESTING

Data from the 42 lime factorial tests on the venturi scrubber and on the spray tower system are given in Table 6-2.

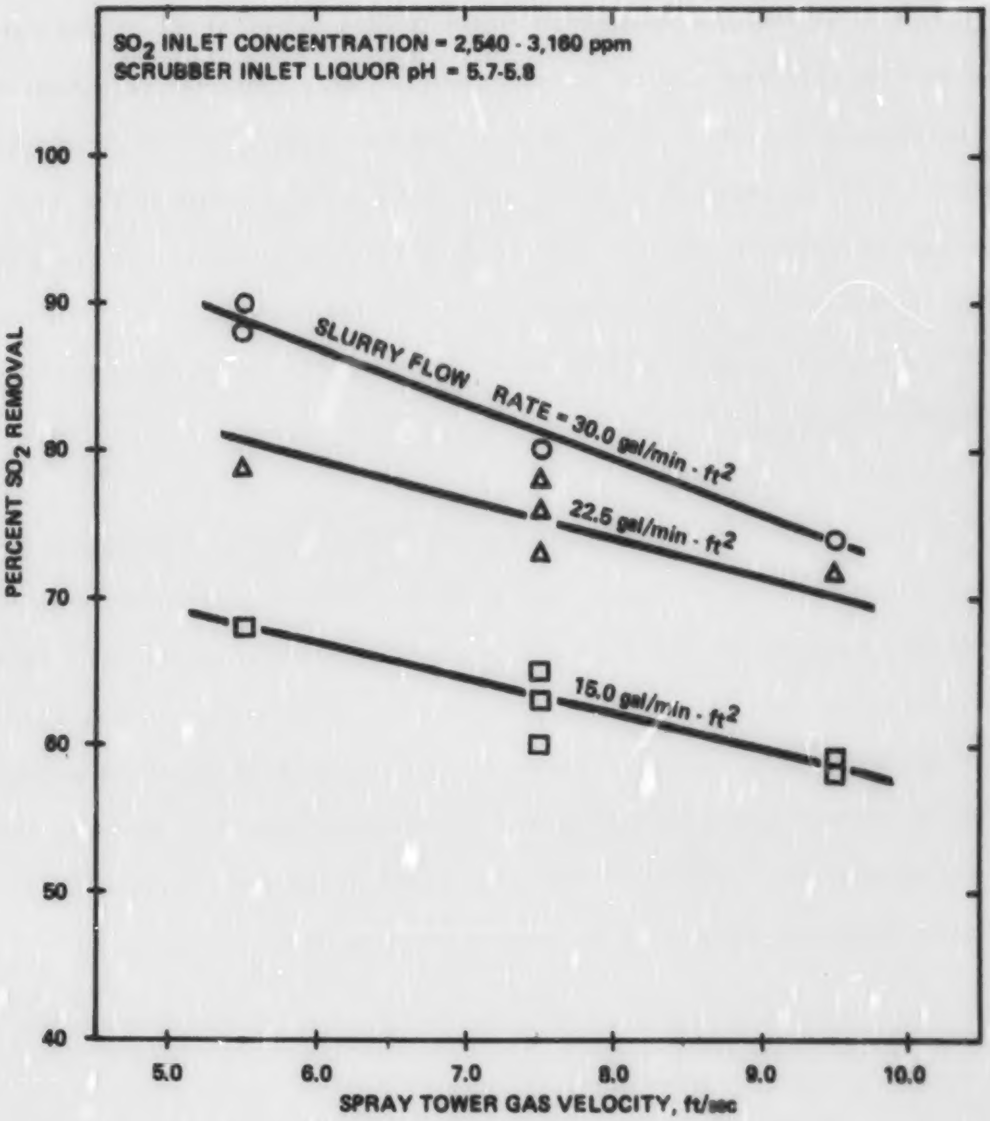

Figure 6-6. Effect of Gas Velocity and Slurry Flow Rate on SO$_2$ Removal - Spray Tower with Limestone

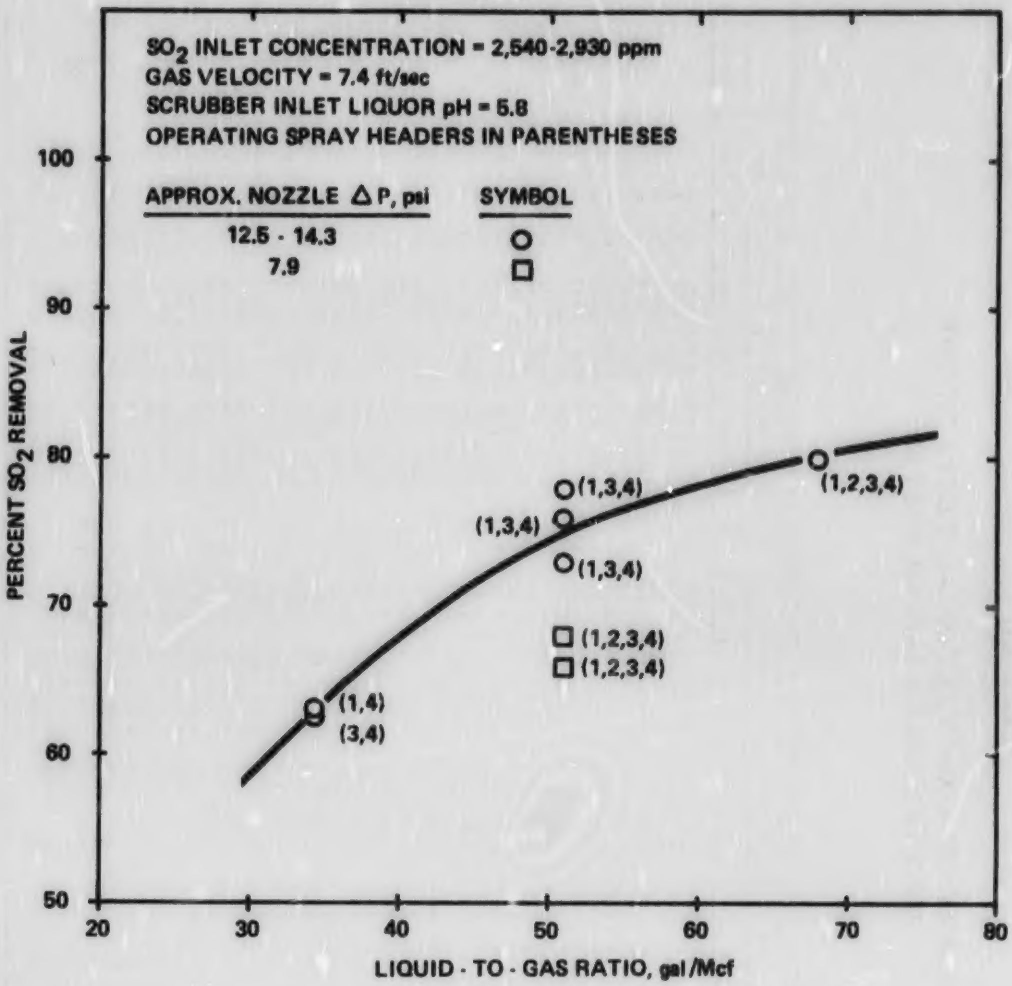

Figure 6-7. Effect of Liquid-to-Gas Ratio and Spray Nozzle Pressure Drop on SO_2 Removal - Spray Tower with Limestone

Table 6-2

SUMMARY OF LIME FACTORIAL TESTS ON THE VENTURI/SPRAY TOWER SYSTEM

Run Number	Gas Rate, acfm	Liquor Rate, gpm		ST Gas Vel., ft/sec	L/G gal/Mcf		Press. Drop, in. H_2O		Scrubber Inlet Liquor pH		Scrubber Outlet Liquor pH	Inlet SO_2 Conc., ppm		Percent SO_2 Removal		No. of Spray Headers Used	Replicate Number
		V	ST		V	ST	V	ST	Range	Avg.		Range	Avg.	Range	Avg.		
VST001	27500	135	0	7.4	6.1	0	1.5	1.9	8.64-9.11	8.98	4.07	2560-2880	2720	6-12	9	0	
VST002	27500	135	0	7.4	6.1	0	1.3	2.0	7.97-8.31	8.13	5.13	2514-2560	2529	4- 7	5	0	A
VST003	27500	160	0	7.4	7.2	0	2.1	1.1	5.91-5.91	5.91		2760-2760	2760	4- 4	4	0	
VST004	27500	135	0	7.4	6.1	0	2.0	1.8	7.96-8.10	8.09		2400-2440	2432	2- 9	5	0	A
VST005	35000	300	0	9.4	10.7	0	9.0	3.7	7.85-8.07	7.97	4.92	2480-2800	2680	21-24	21	0	
VST006	20000	600	0	5.4	37.4	0	9.1	1.8	7.93-8.15	8.02		2680-2720	2704	43-45	44	0	B
VST007	35000	600	0	9.4	21.4	0	9.2	4.5	7.90-8.14	8.08	4.95	2600-2800	2714	30-35	32	0	
VST008	27500	600	0	7.4	27.2	0	9.1	2.5	7.96-8.26	8.11	4.70	2520-2600	2580	37-40	39	0	C
VST009	20000	600	0	5.4	37.4	0	8.8	1.0	7.99-8.27	8.08		2400-2600	2474	42-46	45	0	B
VST010	20000	300	0	5.4	18.7	0	8.3	0.6	8.04-8.10	8.10		2480-2600	2520	25-31	28	0	
VST011	27500	600	0	7.4	27.2	0	5.9	0.9	7.61-8.29	8.02	4.38	2520-2780	2676	28-34	31	0	
VST012	27500	600	0	7.4	27.2	0	12.2	2.2	7.93-8.12	8.01	4.45	2600-2800	2703	34-36	35	0	
VST013	27500	600	0	7.4	27.2	0	9.0	2.1	7.93-8.32	8.13	4.78	2720-2840	2773	31-35	34	0	C
VST014	27500	620	0	7.4	27.2	0	9.1	2.4	6.98-7.15	7.09		2640-2800	2677	31-35	32	0	
VST015	27500	600	0	7.4	27.2	0	9.0	2.0	8.95-9.08	9.03	4.98	2760-2960	2856	45-48	46	0	
VST016	27500	600	0	7.4	27.2	0	9.2	2.1	7.68-8.28	8.05		2600-2920	2760	31-38	36	0	C
VST017	35000	140	1125	9.4	5.0	40	3.4	3.8	7.72-8.26	8.05	4.67	2800-3000	2949	70-75	73	3(1,3,4)	
VST018	35000	145	750	9.4	5.2	27	3.1	3.0	7.80-8.13	7.96		2480-2640	2531	57-59	58	2(3,4)	D
VST019	20000	140	1500	5.4	8.7	94	1.2	1.7	7.93-8.30	8.10	4.80	2920-3100	2997	95-96	95	4	E
VST020	27500	145	1125	7.4	6.6	51	2.1	2.3	7.90-8.12	8.02		2760-2840	2800	82-85	84	3(1,3,4)	F
VST021	20000	145	1125	5.4	9.0	70	1.4	1.4	7.97-8.11	8.04	5.03	2600-2800	2727	89-91	90	3(1,3,4)	
VST022	35000	140	750	9.4	5.0	27	3.2	3.4	7.95-8.20	8.08	4.64	2480-2560	2514	56-61	59	2(3,4)	D
VST023	27500	140	1500	7.4	6.3	68	1.9	2.4	7.85-8.18	8.01		2827-3041	2907	86-89	87	4	
VST024	35000	150	1500	9.4	5.3	53	3.6	4.0	7.89-8.18	8.05	4.76	2867-2997	2917	74-79	77	4	
VST025	27500	140	1125	7.4	6.3	51	2.2	2.6	7.99-8.19	8.08		2600-2680	2640	81-85	82	3(1,3,4)	F
VST026	20000	140	750	5.4	8.7	47	1.2	1.3	7.81-8.32	8.05		2440-2560	2483	74-78	77	2(3,4)	
VST027	20000	140	1500	5.4	8.7	94	1.1	1.7	7.93-8.20	8.04		3056-3100	3132	95-96	95	4	E
VST028	27500	145	750	7.4	6.6	34	2.1	1.9	8.00-8.07	8.03		2600-2720	2646	63-66	65	2(3,4)	H
VST029	27500	140	1125	7.4	6.3	51	2.0	2.8	6.53-6.98	6.78		2560-2680	2632	70-72	71	3(1,3,4)	
VST030	27500	145	1125	7.4	6.6	51	2.3	2.5	9.04-9.10	9.08	6.50	2560-2720	2640	94-96	95	3(1,3,4)	K
VST031	27500	140	1125	7.4	6.3	51	2.7	2.3	5.99-6.30	6.11	4.72	2600-2640	2623	66-68	67	3(1,3,4)	G
VST032	27500	145	1125	7.4	6.6	51	2.1	2.7	8.06-8.15	8.00		2600-2680	2640	79-82	81	3(1,3,4)	F
VST033	27500	145	1125	7.4	6.6	51	2.3	2.4	5.90-6.10	6.00		2520-2680	2595	63-68	67	3(1,3 4)	G
VST035	27500	140	750	7.4	6.3	34	1.9	2.3	7.91-8.07	8.01		2560-2640	2593	65-67	65	2(3,4)	H
VST037	27500	140	750	7.4	6.3	34	2.1	2.1	7.82-8.52	8.20	4.80	2800-2880	2816	67-73	69	2(1,2)	
VST039	27500	150	750	7.4	6.8	34	2.0	2.2	8.02-8.34	8.24		2600-2680	2630	72-80	75	2(1,4)	
VST040	27500	140	1125	7.4	6.3	51	2.2	2.1	7.84-8.12	8.01	4.92	2820-3020	2947	68-75	73	4	J
VST041	27500	145	1125	7.4	6.6	51	2.1	2.6	7.90-8.20	8.05	4.81	2400-2520	2457	82-86	85	3(1,3,4)	F
VST042	27500	140	1125	7.4	6.3	51	2.0	2.6	7.89-8.31	8.06	4.70	2800-2920	2846	69-74	71	4	J
VST044	35000	600	1200	9.4	21.4	43	9.3	4.8	7.79-8.32	8.05		2840-2981	2926	79-82	80	4	
VST045	35000	150	0	9.4	5.3	0	3.1	2.8	8.01-8.13	8.04		2640-2840	2749	1- 5	3	0	
VST047	27500	140	1125	7.4	6.3	51	2.2	2.2	8.90-9.17	9.07		2400-2600	2484	95-98	97	3(1,3,4)	K

6.4.1 Venturi Scrubber Lime Results

Seventeen lime factorial tests were run on the venturi scrubber (no slurry flow to the spray tower). Independent variables tested with the venturi lime system were:

- Gas flow rate
- Slurry recirculation rate
- Scrubber inlet liquor pH
- Venturi pressure drop

Percent SO_2 removal by the venturi scrubber increases with increasing scrubber inlet liquor pH. Figure 6-8 shows this effect at 9 inches of H_2O pressure drop across the venturi and at a liquid-to-gas ratio of 27 gal/Mcf.

Figure 6-9 shows the effects on SO_2 removal in the venturi scrubber when slurry and gas flow rates are varied independently. SO_2 removal is enhanced by increasing slurry rate or decreasing gas rate (either of which increases liquid-to-gas ratio). The data are replotted in Figure 6-10 to illustrate the positive effect of liquid-to-gas ratio on percent SO_2 removal. The figure also shows that a change in gas rate at constant liquid-to-gas ratio appears to have little effect on SO_2 removal.

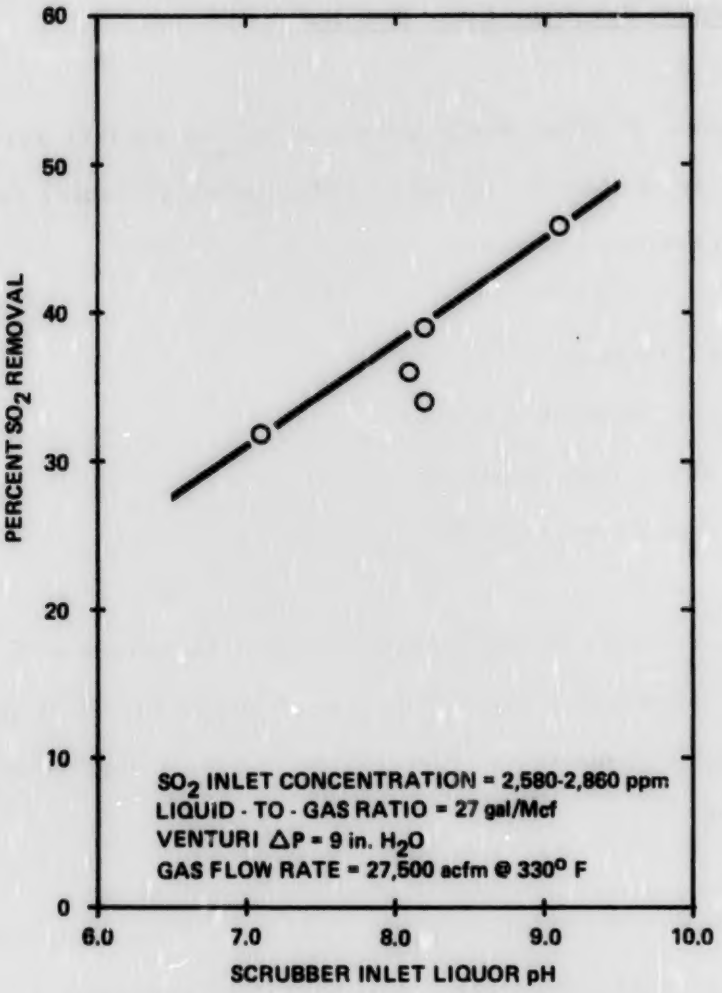

Figure 6-8. Effect of Scrubber Inlet Liquor pH on SO_2 Removal - Venturi Scrubber with Lime

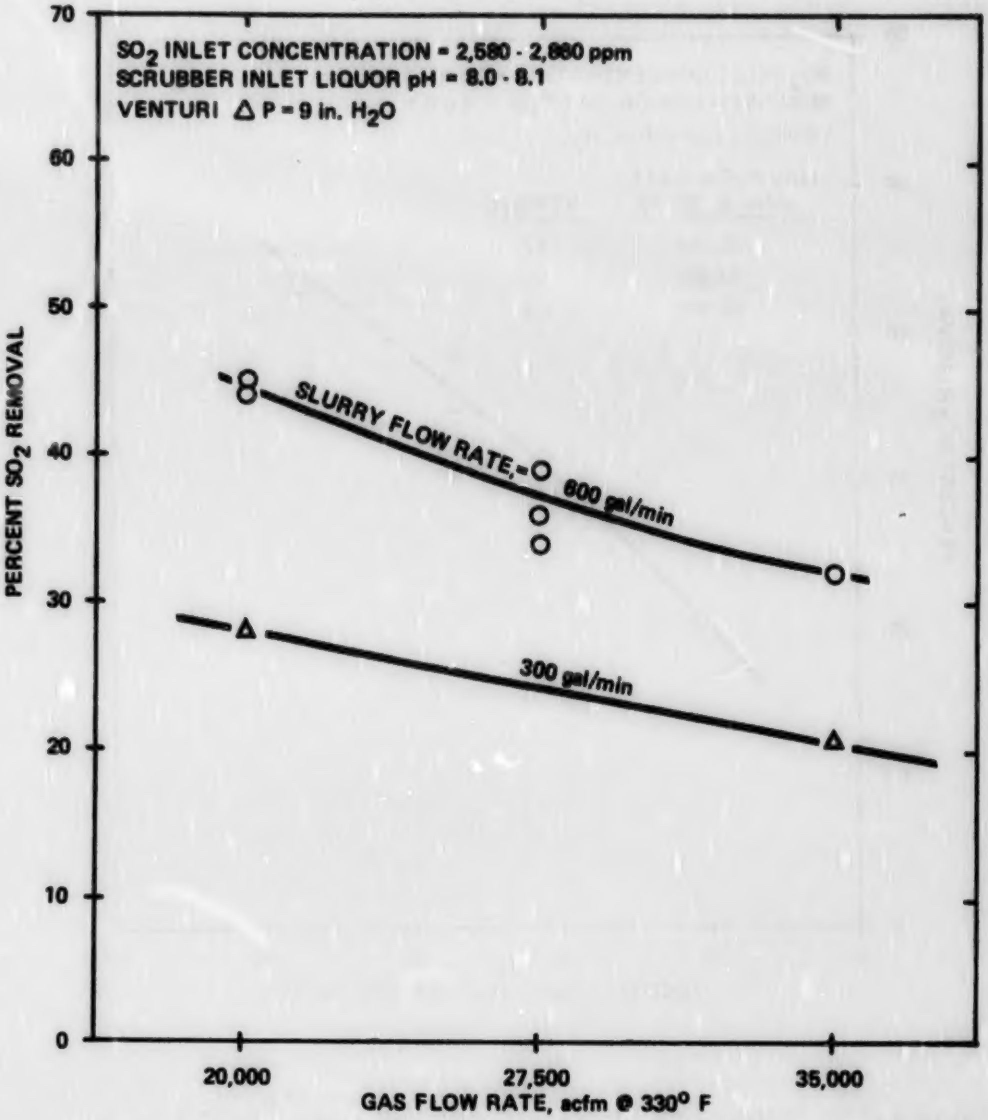

Figure 6-9. Effect of Slurry and Gas Flow Rates on SO$_2$ Removal - Venturi Scrubber with Lime

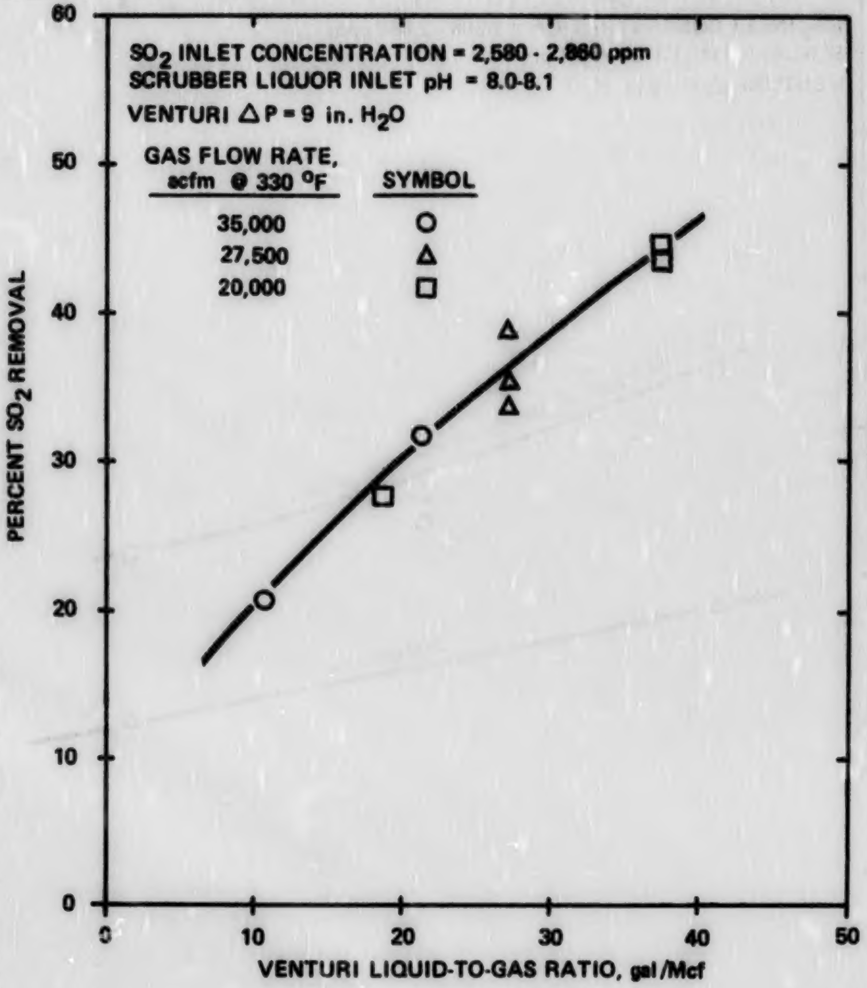

Figure 6-10. Effect of Liquid-to-Gas Ratio and Gas Flow Rate on SO_2 Removal - Venturi Scrubber with Lime

Figure 6-11 shows that percent SO_2 removal increases only slightly with increasing pressure drop at a liquid-to-gas ratio of 27 gal/Mcf. The effect is much stronger with limestone addition at a pH of 5.7 than with lime at a pH of 8.0 (see Figure 6-4).

6.4.2 Spray Tower Lime Results

Twenty-five spray-tower-only tests were run with a minimum pressure drop across the venturi and a minimum (150 gpm) slurry flow rate to the venturi, as discussed in Subsection 6.3.2. Independent variables tested with the spray tower lime system were:

- Gas flow rate
- Slurry recirculation rate
- Scrubber inlet liquor pH
- Number of spray headers
- Spray nozzle pressure drop

Figure 6-12 shows that percent SO_2 removal is enhanced with increasing scrubber inlet liquor pH and increasing liquid-to-gas ratio.

Figure 6-13 shows the results of tests in which nozzle pressure drops and the configuration of the operating spray headers were varied. SO_2 removal was enhanced by about 10 percentage points when the nozzle

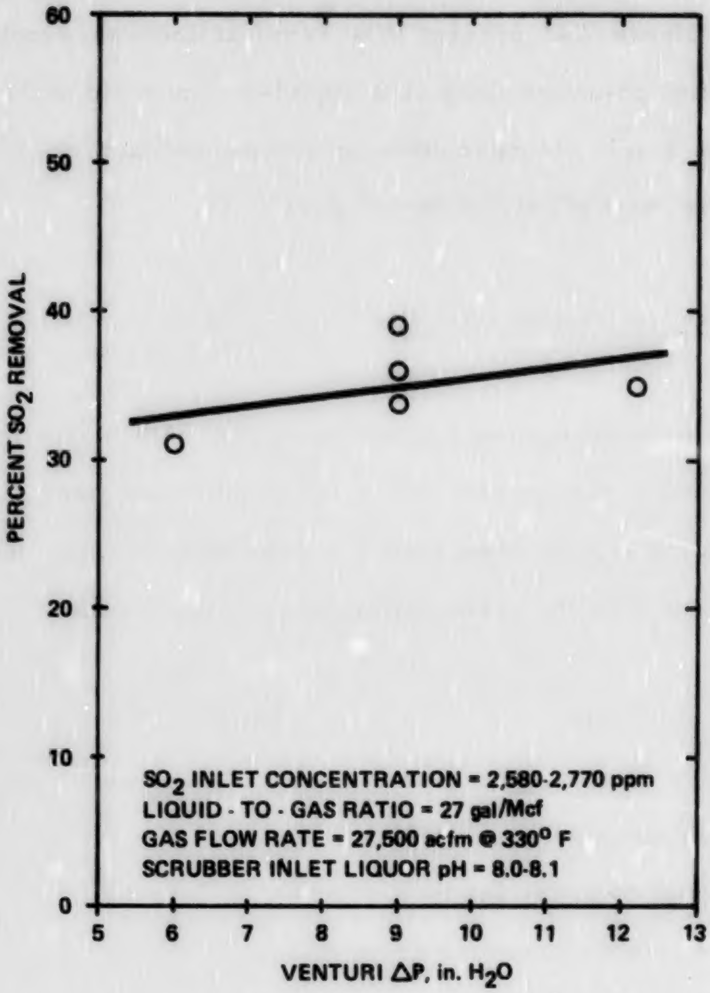

Figure 6-11. Effect of Venturi Pressure Drop on SO_2 Removal - Venturi Scrubber with Lime

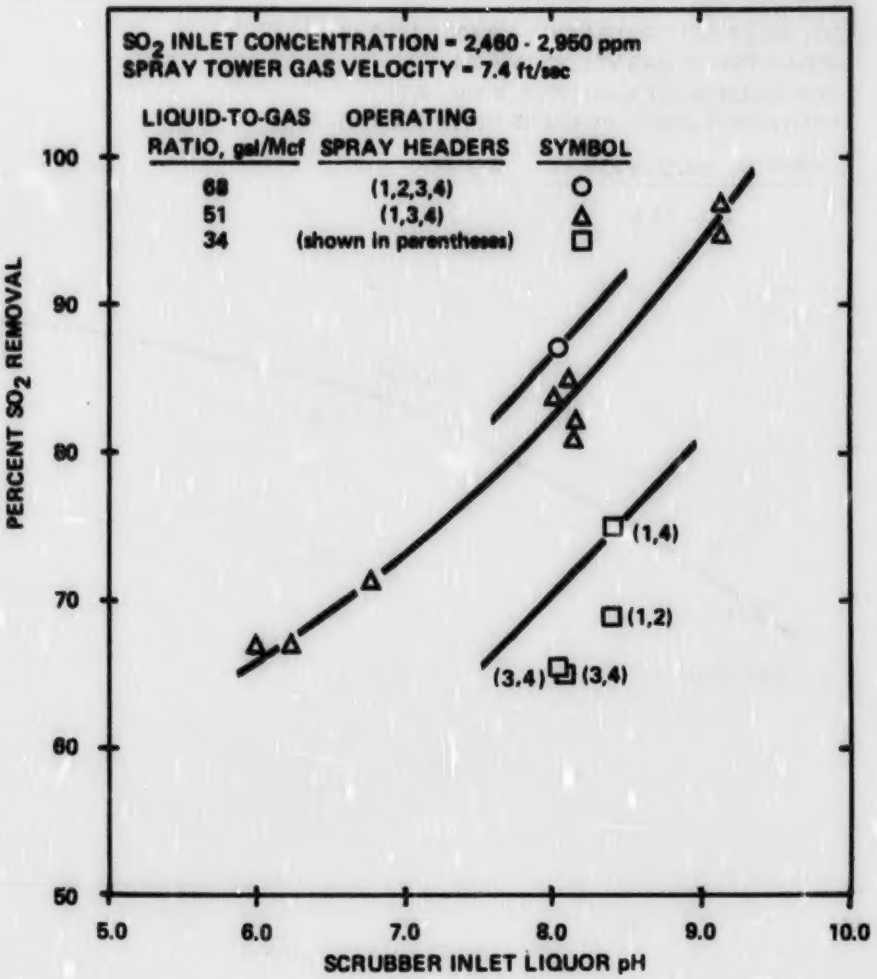

Figure 6-12. Effect of Scrubber Inlet Liquor pH and Liquid-to-Gas Ratio on SO_2 Removal - Spray Tower with Lime

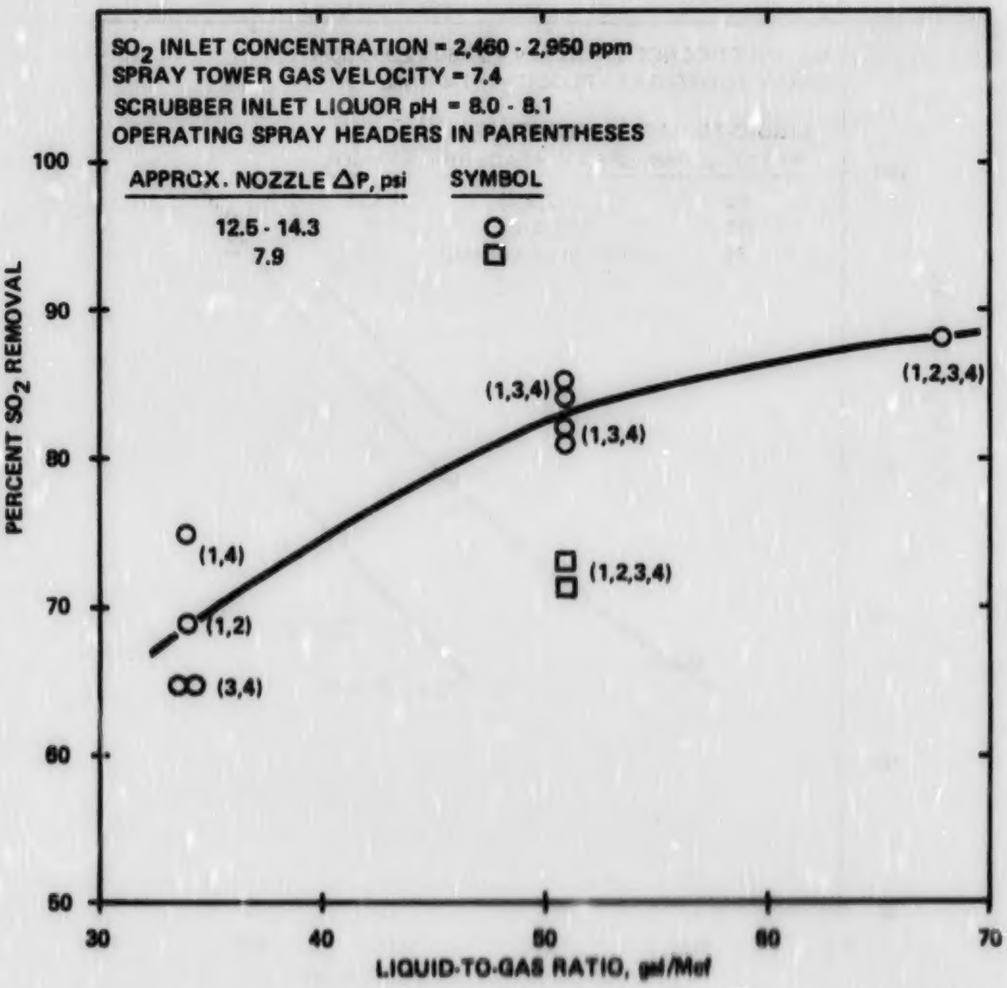

Figure 6-13. Effect of Liquid-to-Gas Ratio and Spray Nozzle Pressure Drop on SO_2 Removal - Spray Tower with Lime

pressure drop was increased from 7.9 to 14.3 psi by decreasing the number of spray headers from four (1, 2, 3, 4) to three (1, 3, 4). Use of the top two headers (No. 3 and No. 4) or the bottom two headers (No. 1 and No. 2) was less effective for SO_2 removal than use of the top (No. 4) and bottom (No. 1) headers together.

Figure 6-14 shows the effects on SO_2 removal when gas rate and slurry rate are varied independently. SO_2 removal improves with increasing slurry rate or decreasing gas rate. Either of these changes results in a higher liquid-to-gas ratio.

6.5 LIMESTONE TESTING WITH MAGNESIUM OXIDE ADDITION

It has been shown (Reference 4) that addition of MgO to lime/limestone scrubbing systems increases SO_2 removal. The chemistry of magnesium oxidation is discussed in Section 5.3.* To determine the quantitative effect of MgO addition on SO_2 removal by the venturi/spray tower system, 49 limestone/MgO factorial tests were made. Data from these tests are shown in Table 6-3.

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* As explained there, only magnesium ions in stoichiometric excess of the chloride ions present are effective in increasing SO_2 removal. Effective magnesium, $(Mg)_e$, used when discussing magnesium oxide addition, is thus defined as $(Mg^{++} - Cl^- /2.92)$ if $Mg^{++} > Cl^- /2.92$ or as zero if $Mg^{++} \leq Cl^-/2.92$.

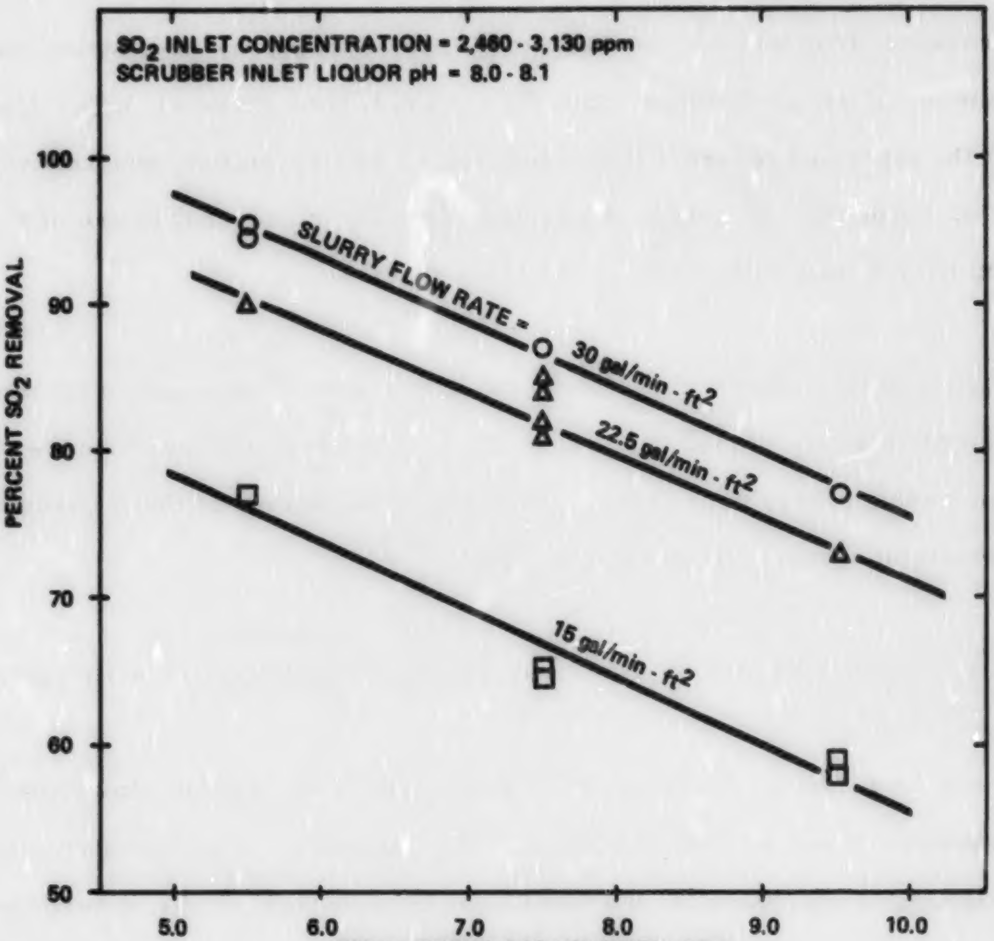

Figure 6-14. Effect of Gas Velocity and Slurry Flow Rate on SO_2 Removal - Spray Tower with Lime

Table 6-3

SUMMARY OF LIMESTONE/MgO FACTORIAL TESTS ON THE VENTURI/SPRAY TOWER SYSTEM

Run Number	Gas Rate, acfm	Liquor Rate, gpm		ST Gas Vel., ft/sec	L/G gal/Mcf		Pressure Drop, in. H_2O		Scrubber Inlet Liquor pH		Scrubber Outlet Liquor pH	Av. Scrubber Inlet Liquor Mg^{++} Conc., ppm	Av. Scrubber Inlet Liquor Cl^- Conc., ppm	Effective Mg^{++} Conc., ppm	Inlet SO_2 Conc., ppm		Percent SO_2 Removal		No. of Spray Headers Used	Replicate Number
		V	ST		V	ST	V	ST	Range	Avg.					Range	Avg.	Range	Avg.		
VMG102	27500	145	1500	7.4	6.6	68	2.0	2.0	5.51-5.58	5.56	5.22	5100	13700	496	2360-2440	2387	80-85	84	4	
VMG103	27500	140	1500	7.4	6.3	68	2.0	2.3	5.19-5.26	5.22		5460	14732	414	2360-2440	2400	69-72	70	4	
VMG104	27500	145	1125	7.4	6.6	51	2.1	2.9	5.75-5.79	5.77	5.34	4900	14000	0	2320-2400	2352	79-81	80	3(1,3,4)	A
VMG105	27500	150	1125	7.4	6.8	51	2.1	2.9	5.46-5.59	5.53		5360	12000	1250	2320-2400	2373	67-71	69	3(1,3,4)	
VMG106	27500	145	1125	7.4	6.6	51	2.3	2.0	5.20-5.29	5.24		4624	11950	531	2440-2480	2457	58-61	59	3(1,3,4)	
VMG107	27500	145	1125	7.4	6.6	51	2.5	2.5	5.68-5.84	5.79		5534	12000	1150	2360-2520	2432	79-81	80	3(1,3,4)	A
VMG108	27500	145	750	7.4	6.6	34	2.3	2.6	5.46-5.59	5.51		5060	13000	1415	2600-2680	2648	52-54	52	2(3,4)	
VMG109	27500	145	750	7.4	6.6	34	2.5	2.7	5.07-5.29	5.20		5432	13500	800	2640-2760	2697	36-46	42	2(3,4)	
VMG110	27500	600	0	7.4	27.2	0	9.0	2.6	5.68-5.83	5.74		5686	14000	811	2400-2600	2520	36-38	37	0	
VMG111	35000	600	0	9.4	21.4	0	9.3	4.2	5.64-5.72	5.68		5460	11100	1658	2280-2360	2326	32-37	35	0	G
VMG112	20000	600	0	5.4	37.4	0	9.0	3.3	5.77-5.95	5.82		5601	13500	977	2160-2400	2337	39-42	41	0	
VMG113	27500	600	0	7.4	27.2	0	9.1	3.2	5.71-5.82	5.76	5.09	11541	15060	6383	3080-3480	3306	50-53	51	0	H
VMG114	35000	600	0	9.4	21.4	0	9.3	5.2	5.62-5.68	5.65		10380	14022	5577	3400-3800	2628	39-45	43	0	
VMG115	27500	600	0	7.4	27.2	0	9.3	3.2	5.73-5.81	5.75	5.05	9937	12700	5560	3200-3400	3283	50-54	52	0	H
VMG116	27500	145	0	7.4	6.6	0	2.3	2.6	5.80-5.85	5.82		10405	12801	6101	3040-3200	3120	6-11	9	0	
VMG117	27500	140	1500	7.4	6.3	68	2.3	3.0	5.46-5.59	5.53		8617	14057	3802	2480-2600	2552	92-96	95	4	B
VMG118	27500	140	1500	7.4	6.3	68	2.2	3.2	5.17-5.23	5.20		8922	12996	4471	2640-2960	2783	84-87	85	4	
VMG119	27500	140	1500	7.4	6.3	68	2.2	3.3	5.46-5.58	5.53		9971	14377	5047	2320-2560	2448	90-95	93	4	B
VMG120	27500	145	1125	7.4	6.6	51	2.2	3.0	5.40-5.56	5.49		9510	15500	4201	2500-2520	2500	70-80	79	3(1,3,4)	E
VMG121	35000	145	1125	9.4	5.2	40	3.7	4.4	5.50-5.58	5.53		9933	17000	4111	2480-2520	2507	75-77	76	3(1,3,4)	F
VMG122	20000	145	1125	5.4	9.0	70	1.5	1.6	5.41-5.56	5.51		9413	16685	3698	2320-2500	2417	84-87	86	3(1,3,4)	
VMG123	27500	150	1125	7.4	6.8	51	2.6	2.6	5.09-5.34	5.23		8720	15265	3492	2440-2560	2520	66-70	68	3(1,3,4)	
VMG124	27500	135	1125	7.4	6.1	51	1.8	3.0	5.74-5.91	5.79		8955	15087	3788	2420-2500	2460	85-92	87	3(1,3,4)	
VMG125	27500	145	1125	7.4	6.6	51	3.0	2.7	5.44-5.63	5.51		9613	16330	4020	2520-2640	2593	76-81	78	3(1,3,4)	E
VMG126	35000	145	1125	9.4	5.2	40	4.7	4.2	5.47-5.55	5.51		8610	15080	3171	2320-2400	2360	71-75	73	3(1,3,4)	F
VMG127	27500	140	750	7.4	6.3	34	2.3	2.9	5.42-5.60	5.49	5.17	9190	14310	4286	2800-3060	2964	61-70	67	2(3,4)	D
VMG128	27500	145	750	7.4	6.6	34	2.3	2.0	5.12-5.26	5.19		10425	14067	5607	3160-3400	3300	60-61	60	2(3,4)	
VMG129	27500	145	750	7.4	6.6	34	2.5	2.9	5.48-5.58	5.52		9729	14676	4702	2160-2760	2428	70-73	71	2(3,4)	D
VMG130	27500	145	1500	7.4	6.6	68	2.9	3.1	5.54-5.60	5.57		12060	9033	8692	3480-3560	3528	98-98	98	4	
VMG131	27500	145	1500	7.4	6.6	68	2.5	3.3	5.20-5.25	5.23		11512	9585	8229	3700-3800	3750	95-96	95	4	
VMG132	27500	145	1125	7.4	6.6	51	3.1	3.2	5.21-5.29	5.25	4.93	13600	9407	10378	3000-3606	3263	87-94	91	3(1,3,4)	C
VMG133	27500	145	1125	7.4	6.6	51	2.9	2.6	5.72-5.87	5.81		11083	8890	8038	3120-3440	3270	91-99	96	3(1,3,4)	
VMG134	27500	145	1125	7.4	6.6	51	2.5	2.7	5.48-5.54	5.50	4.93	12103	8410	9302	3400-3520	3440	97-98	97	3(1,3,4)	J
VMG135	27500	140	1125	7.4	6.3	51	2.0	2.4	5.15-5.22	5.18	5.02	12103	8727	9194	2260-2480	2370	87-89	88	3(1,3,4)	C
VMG136	27500	165	750	7.4	7.5	34	4.4	3.1	5.12-5.26	5.25	4.74	11480	8342	8631	2400-2640	2535	84-85	85	2(3,4)	
VMG137	27500	145	750	7.4	6.6	34	2.5	2.5	5.51-5.59	5.54	4.74	12300	6901	9917	2640-2720	2693	90-93	92	2(3,4)	I
VMG138	27500	600	0	7.4	27.2	0	8.9	2.0	5.70-5.82	5.76	5.35	13034	10874	9310	3320-3466	3377	83-86	85	0	
VMG139	20000	600	0	5.4	37.4	0	9.1	1.1	5.70-5.80	5.76		13106	12011	8992	3320-3380	3345	85-86	86	0	
VMG140	35000	600	0	9.4	21.4	0	9.0	4.0	5.65-5.86	5.74	5.21	11329	11600	7356	3200-3340	3290	80-82	81	0	
VMG141	27500	145	0	7.4	6.6	0	2.1	2.2	5.81-6.09	5.96		11242	7723	8597	3000-3200	3133	1- 6	3	0	
VMG143	35000	600	0	9.4	21.4	0	9.0	4.7	5.69-5.83	5.76		5696	14100	867	2080-2200	2145	32-37	35	0	G
VMG144	27500	145	750	7.4	6.6	34	2.4	3.0	5.49-5.60	5.54		9481	15300	4213	2520-2800	2640	73-75	74	2(3,4)	D
VMG145	35000	145	750	9.4	5.2	27	5.3	4.0	5.41-5.58	5.48	5.00	11350	7039	8665	2640-2800	2713	78-82	81	2(3,4)	
VMG146	35000	145	1125	9.4	5.2	40	4.1	4.3	5.43-5.49	5.45	5.10	12050	9407	9620	3600-3720	3663	94-94	94	3(1,3,4)	
VMG147	27500	145	750	7.4	6.6	34	3.1	2.6	5.35-5.48	5.42	5.13	12012	8497	9102	3040-3160	3075	82-84	83	2(3,4)	I
VMG148	27500	140	1125	7.4	6.3	51	3.2	2.6	5.50-5.54	5.53	5.13	11354	9082	8243	2360-2520	2440	95-96	96	3(1,3,4)	J
VMG149	27500	600	0	7.4	27.2	0	9.2	5.7	5.75-5.91	5.85	5.35	6280	4819	4629	3100-3320	3246	35-40	38	0	H
VMG150	27500	145	350	7.4	6.6	16	4.0	3.9	5.17-5.23	5.20	4.72	13062	8520	10144	3400-3560	3492	41-46	45	1(1)	
VMG151	27500	140	480	7.4	6.3	22	2.9	2.1	5.27-5.30	5.28	5.10	12125	8461	9227	2840-3240	3027	52-55	53	1(1)	

6.5.1 Venturi Scrubber Limestone/MgO Results

Eleven limestone/magnesium oxide tests were run on the venturi scrubber with no slurry flow to the spray tower. Independent variables tested with this system were:

- Gas flow rate
- Effective magnesium ion concentration in the recirculating liquor

Two additional runs, at minimum slurry recirculation rate (145 gpm) and minimum venturi pressure drop (2 in. H_2O), were made to demonstrate that SO_2 removal in the venturi could be neglected when running the spray tower factorial tests. SO_2 removal under minimum venturi conditions was less than 10 percent up to 6000 ppm effective magnesium ion concentration.

Figure 6-15 illustrates the effect of effective magnesium concentration in the recirculating slurry liquor on percent SO_2 removal by the venturi scrubber at a pressure drop of 9 inches of H_2O and a slurry flow rate of 600 gal/min. As the effective magnesium ion concentration increases from 1000 ppm to 9000 ppm, SO_2 removal increases from 35 percent to 85 percent. The removal increases more rapidly above about 6000 ppm magnesium.

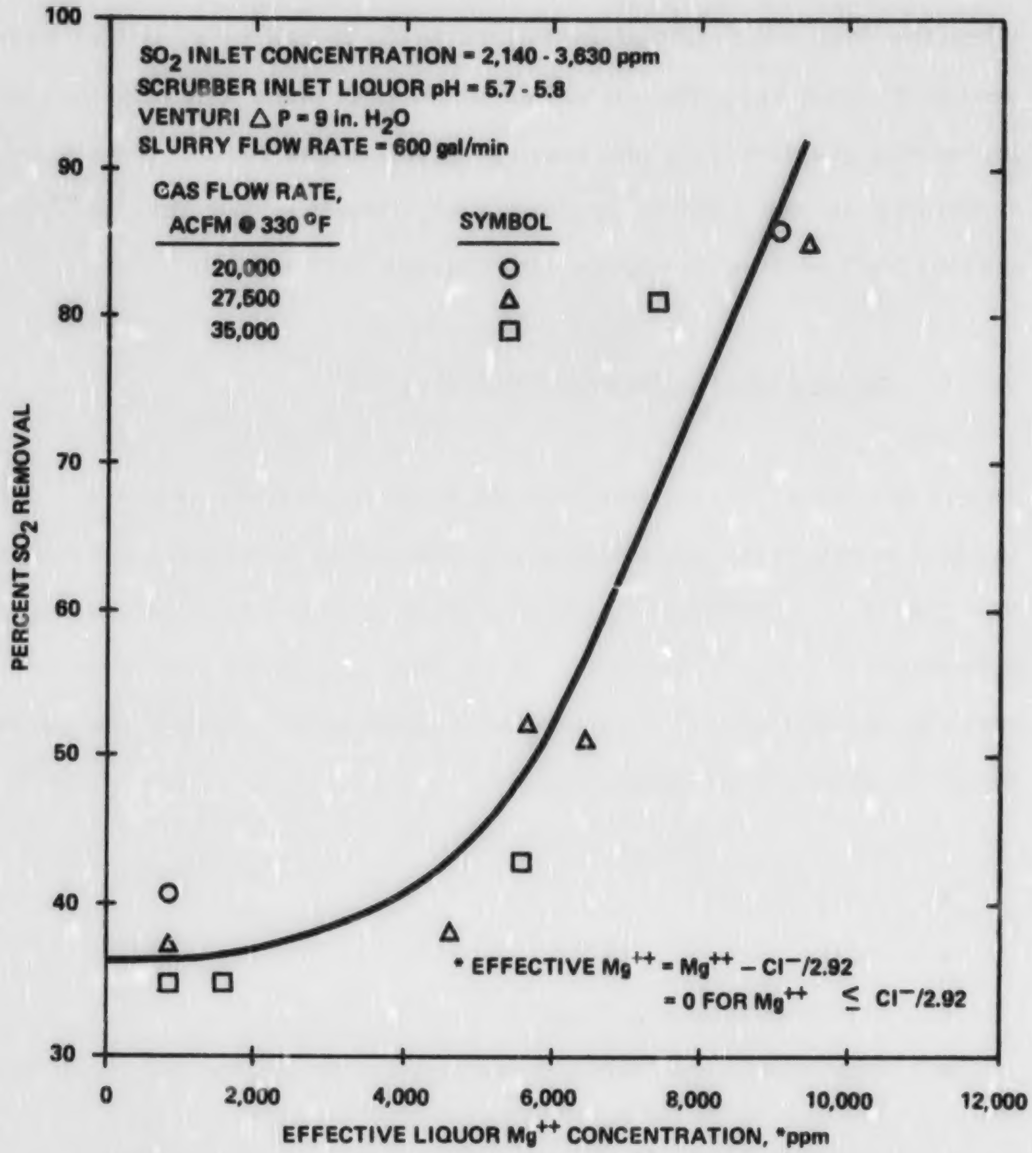

Figure 6-15. Effect of Liquor Magnesium-Ion Concentration and Gas Flow Rate on SO_2 Removal - Venturi Scrubber with Limestone

When the data are replotted in Figure 6-16, it can be seen that percent SO_2 removal by the venturi scrubber decreases only slightly with increasing gas flow rate (decreasing liquid-to-gas ratio). This result is similar to the results obtained with limestone and lime slurries without MgO addition (compare with Figures 6-2 and 6-9).

6.5.2 Spray Tower Limestone/MgO Results

Thirty-six spray tower limestone/MgO factorial tests were run. As in other spray tower factorial tests, these tests were performed with the venturi at a minimum pressure drop and slurry flow rate (see Subsection 6.3.2). Under these circumstances, the effects of the venturi can be neglected. Independent variables tested with the spray tower limestone/MgO were:

- Gas flow rate
- Slurry recirculation rate
- Scrubber inlet liquor pH
- Effective magnesium ion concentration in the recirculating liquor

Figure 6-17 shows the effect of scrubber liquor magnesium ion concentration on percent SO_2 removal by the spray tower at different levels of scrubber inlet liquor pH. Increasing either the magnesium ion concentration or pH increases the percent SO_2 removal. The data

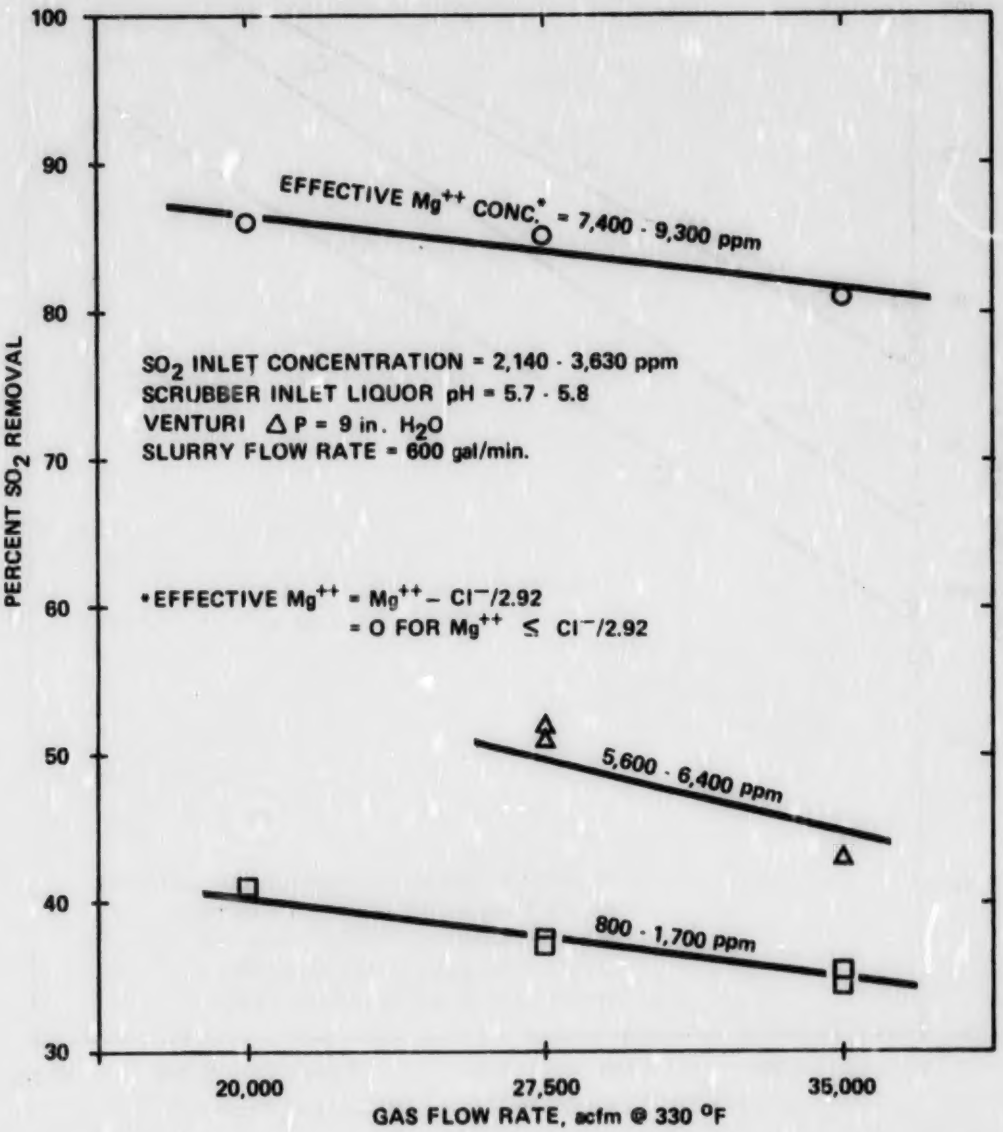

Figure 6-16. Effect of Gas Flow Rate and Liquor Magnesium-Ion Concentration on SO_2 Removal - Venturi Scrubber with Limestone

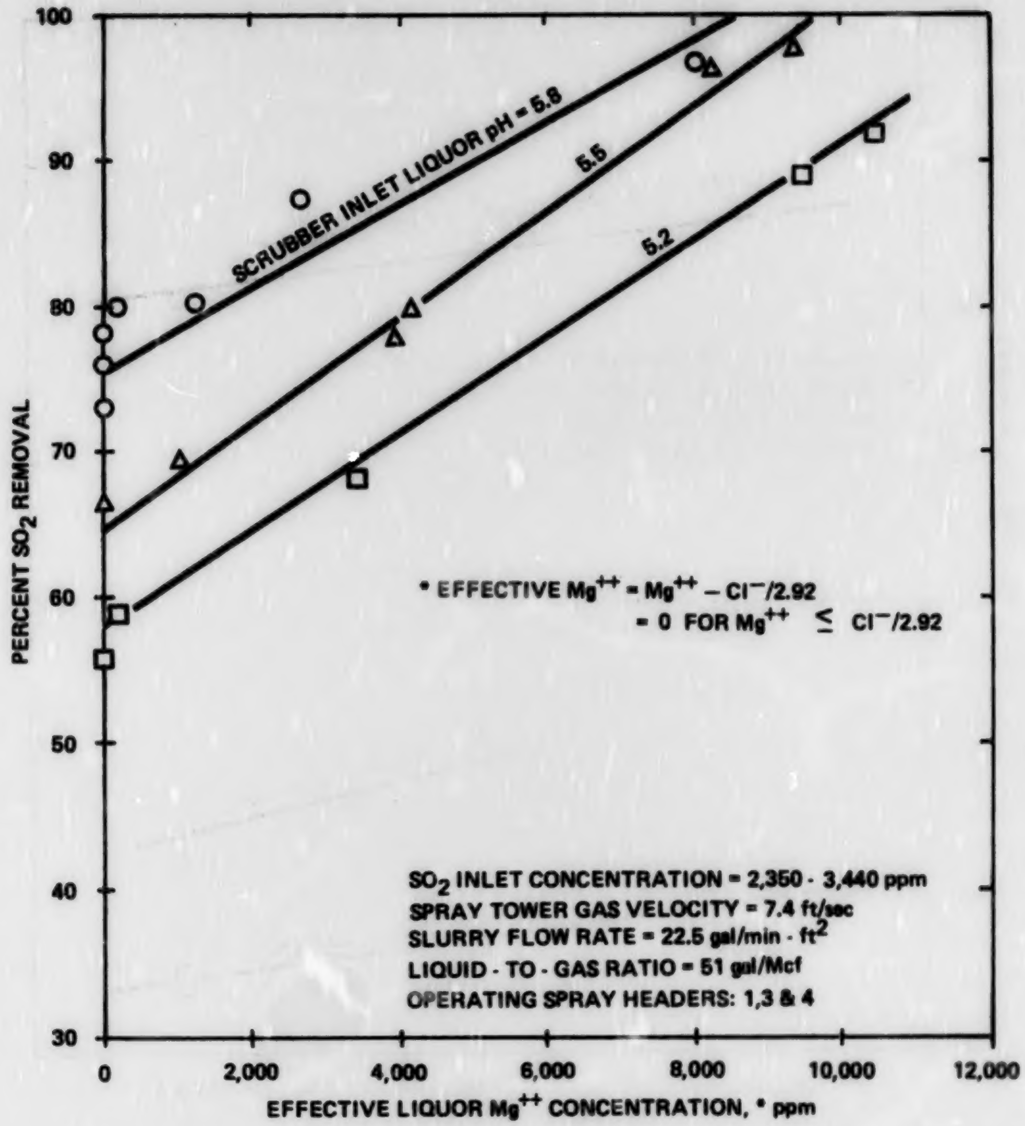

Figure 6-17. Effect of Liquor Magnesium-Ion Concentration and Scrubber Inlet Liquor pH on SO_2 Removal - Spray Tower with Limestone

are replotted in Figure 6-18 to show the effect of scrubber inlet liquor pH at constant effective magnesium ion concentration.

Figure 6-19 shows how SO_2 removal is improved with increasing slurry flow rate and effective magnesium ion concentration.

6.6 LIME TESTING WITH MAGNESIUM OXIDE ADDITION

Seven lime factorial tests with MgO addition were conducted in the venturi/spray tower system during November 1974. The effective magnesium ion concentration during these tests was about 2000 ppm. Results are presented in Table 6-4.

In two runs with the venturi only (600 gpm, 9 in. H_2O) SO_2 removal was about 35 percent over a scrubber inlet liquor pH range of 6.3 to 6.9. In a third run at minimum venturi conditions (150 gpm, 1.4 in. H_2O) SO_2 removal was negligible.

Figure 6-20 shows the percent SO_2 removal achieved in the spray tower for a scrubber inlet liquor pH range of 6.0 to 7.0.

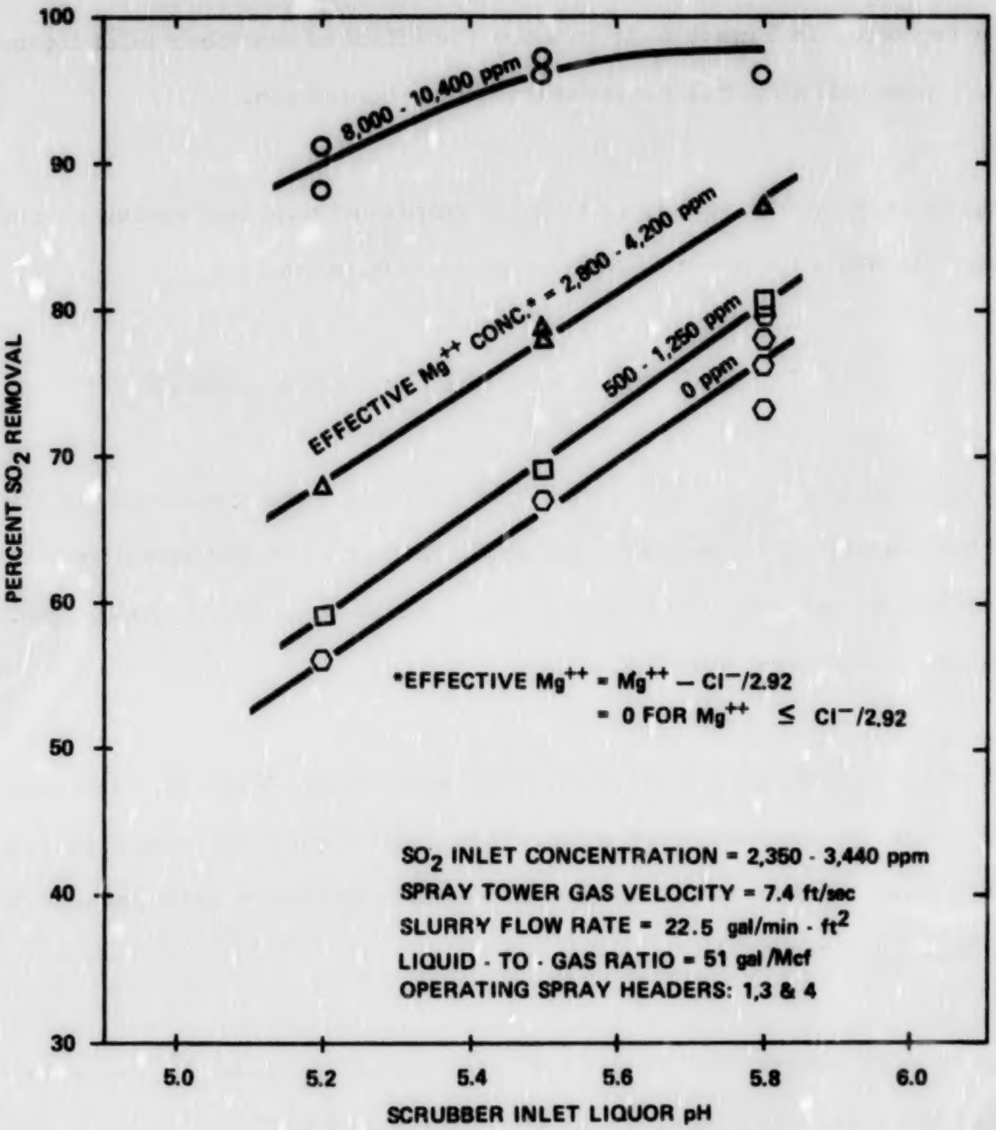

Figure 6-18. Effect of Scrubber Inlet Liquor pH and Liquor Magnesium-Ion Concentration on SO_2 Removal - Spray Tower with Limestone

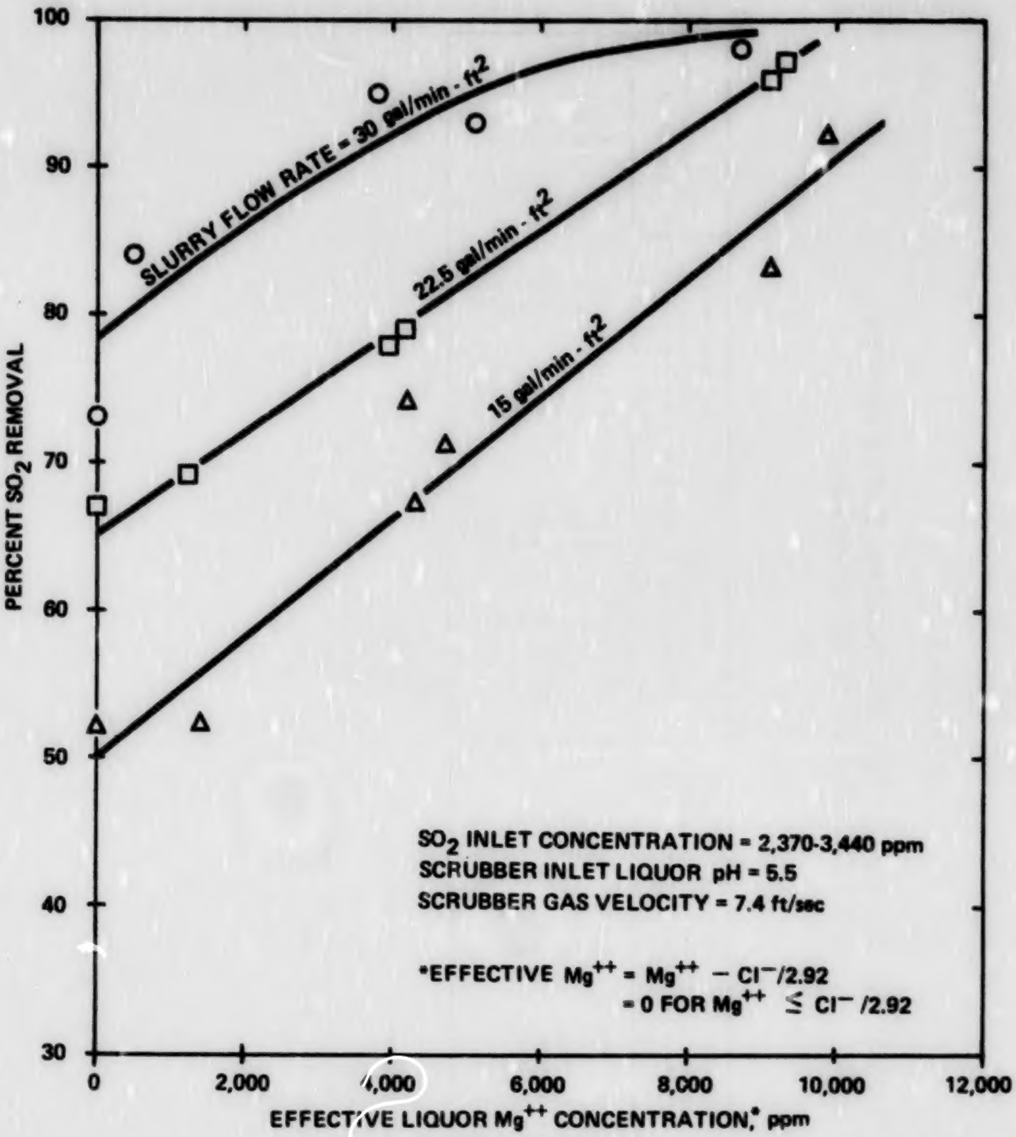

Figure 6-19. Effect of Effective Magnesium-Ion Concentration and Slurry Flow Rate on SO_2 Removal - Spray Tower with Limestone

Table 6-4

SUMMARY OF LIME/MgO FACTORIAL TESTS ON THE VENTURI/SPRAY TOWER SYSTEM

Run No.	Gas Rate, acfm	Liquor Rate, gpm		ST Gas Vel., ft/sec	L/G, gal/Mcf		Press. Drop, in. H_2O		Scrubber Inlet Liquor pH		Scrubber Outlet Liquor pH
		V	ST		V	ST	V	ST	Range	Avg	
612-1A	25000	600	1200	6.7	30	60	8.9	3.1	5.9-6.0	6.0	4.9
613-1A	25000	600	0	6.7	30	0	9.1	2.2	6.2-6.4	6.3	5.1
614-1B	25000	150	1200	6.7	7.5	60	2.5	2.8	5.9-6.3	6.1	5.2
615-1A	25000	150	1200	6.7	7.5	60	2.0	2.8	6.9-7.1	7.0	5.5
615-1B	25000	150	1200	6.7	7.5	60	2.7	2.6	6.9-7.1	7.0	5.3
616-1A	25000	600	0	6.7	30	0	9.0	2.4	6.8-7.0	6.9	4.9
617-1A	25000	150	0	6.7	7.5	0	1.7	1.4	6.15	6.15	--

Note: Other test conditions, same for all runs, are:

Percent solids recirculated = 8%
E.H.T. residence time = 6 - 18 min. (constant tank level)
Fresh lime slurry added to scrubber downcomer

Table 6-4 (continued)

SUMMARY OF LIME/MgO FACTORIAL TESTS ON THE VENTURI/SPRAY TOWER SYSTEM

Run No.	Avg. Liq. Mg^{++} Conc., ppm	Avg. Liq. Cl^- Conc., ppm	Avg. Liq. Effective Mg^{++} Conc., ppm	Inlet SO_2 Conc., ppm		Percent SO_2 Removal		No. of Spray Hdr. Used	Rep.
				Range	Avg.	Range	Avg.		
612-1A	3200	2800	2240	2760-3120	2940	82-95	87	4	
613-1A	3200	3200	2100	2900-3100	3000	33-37	35	0	
614-1B	3350	4100	1950	2200-2800	2500	81-89	85	4	
615-1A	3400	3550	2180	2100-2700	2400	93-95	94	4	A
615-1B	3100	4250	1640	2300-2900	2600	93-95	94	4	A
616-1A	3400	3500	2200	2500-2900	2700	34-38	36	0	
617-1A	3200	3200	2100	2500	2500	0	0	0	

Note: Other test conditions, same for all runs, are:

Percent solids recirculated = 8%
E.H.T. residence time = 6 - 18 min. (constant tank level)
Fresh lime slurry added to scrubber downcomer

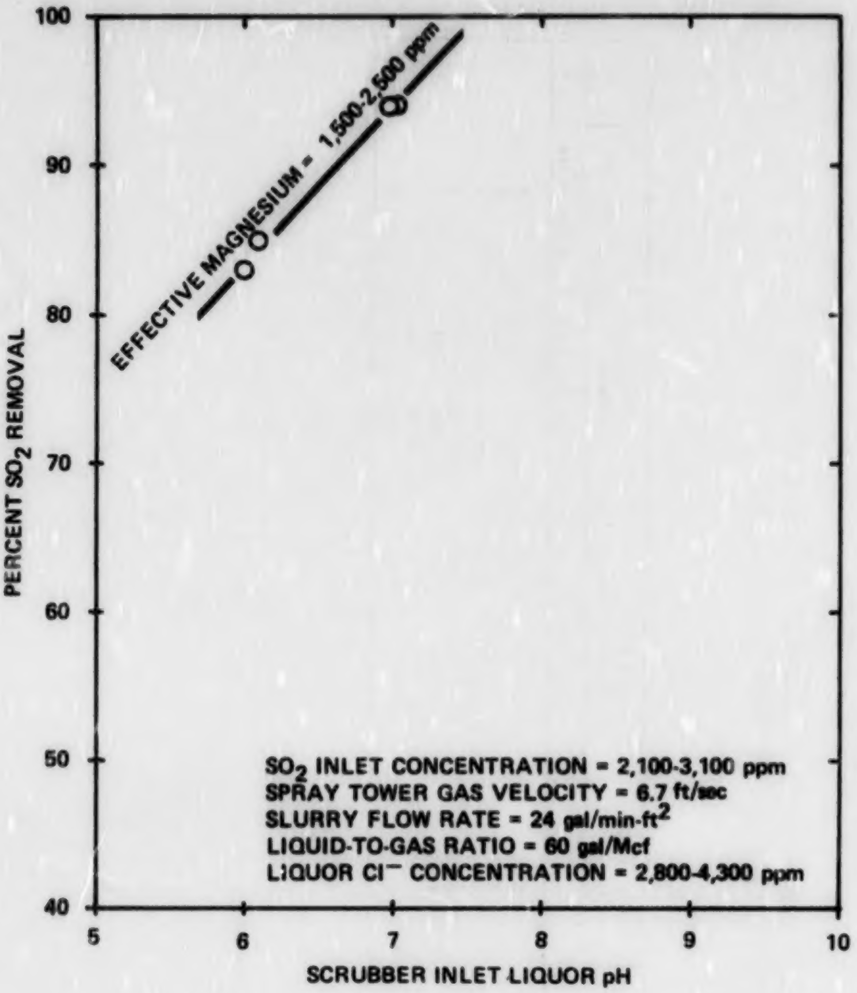

Figure 6-20. Effect of Scrubber Inlet Liquor pH and Effective Liquor Magnesium Concentration on SO_2 Removal - Spray Tower with Lime and Magnesium Addition

Section 7

VENTURI/SPRAY TOWER LIME TEST RESULTS

From late April through early October 1976, the venturi/spray tower system was operated with lime slurry. A total of 16 test runs were made during this period, with an average of about 190 operating hours per run. These tests were divided into two test blocks:

- Testing with fly ash present in the flue gas with MgO addition
- Testing with fly-ash-free flue gas with and without MgO addition

One of the 16 runs was a limestone run which was made because of a temporary shortage of lime at the test facility.

Performance data and test evaluations for each run are presented in this section along with tables of major tests conditions and selected results. A log of the scrubber operating periods is given in Appendix B. Properties of lime, coal, and MgO used during these tests can be found in Appendix C. Appendix D gives a computer-tabulated summary of analytical data. Detailed test conditions and results are summarized in Appendix E. Selected operating data are graphically presented in Appendix F. Average scrubber inlet liquor compositions and the corresponding calculated percent gypsum ($CaSO_4 \cdot 2H_2O$) saturations are given in Appendix G*.

7.1 LIME/MgO TESTING WITH FLUE GAS CONTAINING FLY ASH

The venturi/spray tower system was operated from April through June 1976 with flue gas containing high fly ash loading using lime slurry with added MgO (Runs 629-1A through 633-1A). Table 7-1 lists major test conditions and selected results for these runs. These tests were made to investigate the effect of adding magnesium oxide on the SO_2 absorption efficiency, sulfite oxidation, and gypsum saturation. Since the chloride ion concentration in the scrubber liquor fluctuated and magnesium chloride is not an SO_2 absorbing reagent, an effective magnesium ion concentration (i.e., concentration in excess of equivalent chloride ion concentration) of 2000 ppm was maintained in the scrubber liquor during all of these tests. This concentration corresponded to an MgO addition rate of 2 to 3 lbs of MgO per 100 lbs of CaO added. An evaluation and a discussion of each test are presented below.

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* The degree of liquor saturation with $CaSO_4 \cdot 2H_2O$ at 50°C was calculated with the use of the Bechtel-Modified Radian Equilibrium Computer Program. See Reference 1 for a listing of this program.

Table 7-1

MAJOR TEST CONDITIONS AND SELECTED RESULTS OF VENTURI/SPRAY TOWER LIME TESTING WITH MgO ADDITION

Major Test Conditions[(1)]	629-1A	630-1A	631-1A	632-1A	633-1A
MgO addition	Yes	Yes	Yes	Yes	Yes
Fly ash	Yes	Yes	Yes	Yes	Yes
Gas rate, acfm	35,000	35,000	35,000	35,000	25,000
Spray tower liquor rate, gpm	1400	1400	700	1400	1400
Venturi liquor rate, gpm	600	600	600	~140	~140
Percent solids recirculated	8	8	8	8	8
Effluent residence time, min	3.0	3.0	3.0	3.0	3.0
Scrubber inlet liquor pH (controlled)	6.0	7.0	7.0	7.0	7.0
Effective Mg^{++} concentration, ppm	2000	2000	2000	2000	2000
Venturi pressure drop, in. H_2O	9	9	9	3	2
Number of spray headers	4	4	2 (top 2)	4	4
Selected Results					
On stream hours	267	142	145	151	212
Percent SO_2 removal	75	92	75	82	93
Inlet SO_2 concentration, ppm	3100	3150	3000	2750	2950
SO_2 make-per-pass, m-moles/liter	9.0	10.5	12.5	11.0	9.5
Scrubber inlet liquor $SO_3^=$ concentration, ppm[(2)]	890	770	480	780	1110
Lime utilization, 100x moles SO_2 absorbed/mole Ca added	100	99	98	99	99
Scrubber inlet liquor percent gypsum saturation @ 50°C	75	25	50	20	15
Percent sulfite oxidation	20	15	18	18	15
Scaling	No	No	No	No	No
Mist eliminator restriction, percent[(3)]	2	1	1	<1	<1

Notes:

1) Lime was added to the scrubber downcomer and MgO dry fed to the effluent hold tank in all runs.
2) Total sulfite includes $SO_3^=$ and HSO_3^-.
3) The mist eliminator was not cleaned prior to each run except Run 629-1A.

7.1.1 Venturi/Spray Tower Lime/MgO Run 629-1A

The major test conditions for Run 629-1A are listed in Table 7-1. Other detailed operating conditions can be found in Appendix E. In this run, the scrubber inlet liquor pH was controlled at 6.0 ± 0.2. The chevron mist eliminator was cleaned before the start of the run. The run was interrupted for about 2 days by an unscheduled Boiler No. 10 outage.

The average SO_2 removal efficiency was only 75 percent over an inlet SO_2 concentration range of 2300 to 3900 ppm. The sulfite oxidation averaged about 20 percent. The calculated average gypsum saturation in the scrubber inlet liquor was 75 percent. The mist eliminator was 2 percent restricted in cross-sectional area at the end of the run.*

7.1.2 Venturi/Spray Tower Lime/MgO Run 630-1A

The test conditions for Run 630-1A were the same as for Run 629-1A, except that the scrubber inlet liquor pH was controlled at 7.0 ± 0.2.

During the previous run, the SO_2 removal averaged only 75 percent at the controlled scrubber inlet pH of 6.0. It was theorized from the sulfite-bisulfite and carbonate-bicarbonate equilibria that operation at a higher scrubber inlet pH of 7.0 should result in a higher sulfite and bicarbonate concentration for the neutralization of sulfurous acid and, hence, improve the SO_2 removal efficiency.

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* As visually estimated by the TVA inspector.

Over an inlet SO_2 concentration range of 2400 to 3900 ppm, the average SO_2 removal for Run 630-1A was 92 percent, a significant improvement from 75 percent for Run 629-1A. The sulfite oxidation averaged 15 percent and the calculated gypsum saturation in the scrubber inlet liquor averaged only 25 percent, compared with 20 and 75 percent, respectively, for Run 629-1A. The mist eliminator restriction decreased to 1 percent from 2 percent at the beginning of the run.

7.1.3 Venturi/Spray Tower Lime/MgO Run 631-1A

The test conditions for Run 631-1A were the same as for Run 630-1A (scrubber inlet pH controlled at 7.0 ± 0.2), except that the spray tower slurry flow rate was reduced from 1400 to 700 gpm (the bottom two of the four spray headers were turned off). This gave a liquid-to-gas ratio in the spray tower of only 25 gal/Mcf for Run 631-1A, compared with 50 gal/Mcf for Run 630-1A.

The purpose of Run 631-1A was to observe the effect of the reduced spray tower liquid-to-gas ratio on the SO_2 removal and liquor gypsum saturation. The mist eliminator was not cleaned prior to the run.

The calculated average gypsum saturation in the scrubber inlet liquor was 50 percent for Run 631-1A, compared with 25 percent for Run 630-1A. The average sulfite oxidation was slightly higher at 18 percent. The average SO_2 removal dropped to 75 percent for this run, as was expected from the lower spray tower liquid-to-gas ratio. The mist eliminator condition remained essentially unchanged throughout the run, with 1 percent restriction at the end of the run.

7.1.4 Venturi/Spray Tower Lime/MgO Run 632-1A

Run 632-1A was tested under the same conditions as for Run 630-1A, except that the adjustable venturi plug was positioned so that the throat was 100 percent open and the venturi slurry flow rate was 140 gpm (5 gal/Mcf venturi liquid-to-gas ratio), the minimum controllable for flue gas cooling.

The objective of Run 632-1A was to observe the effect of spray-tower-only operation on the SO_2 removal, sulfite oxidation, and liquor gypsum saturation, in comparison with Run 630-1A. The mist eliminator was not cleaned prior to the run.

The SO_2 removal averaged 82 percent at 2200 to 3300 ppm inlet SO_2 concentration, compared with 92 percent at 2400 to 3900 ppm for

Run 630-1A. The average sulfite oxidation was 18 percent and the calculated gypsum saturation in the scrubber inlet liquor was 20 percent, similar to the values obtained in Run 630-1A. The mist eliminator was less than 1 percent restricted at the end of the run.

7.1.5 Venturi/Spray Tower Lime/MgO Run 633-1A

The test conditions for Run 633-1A were the same as for Run 632-1A except that the flue gas flow rate was decreased from 35,000 to 25,000 acfm (spray tower gas velocity reduced from 9.4 to 6.7 ft/sec). This change resulted in liquid-to-gas ratios of 7.0 and 70 gal/Mcf in the venturi and spray tower, respectively.

The purpose of Run 633-1A was to observe the effect of the lower gas rate (higher liquid-to-gas ratio) on the liquor gypsum saturation and SO_2 removal during spray-tower-only operation. The mist eliminator was not cleaned before the start of the run.

The SO_2 removal improved, as expected from the higher liquid-to-gas ratio, to an average 93 percent at 2500 to 3400 ppm inlet SO_2 concentration, as compared with 82 percent at 2200 to 3300 ppm for Run 632-1A. Average sulfite oxidation was 15 percent and calculated gypsum saturation in the scrubber inlet liquor was also 15 percent, both values slightly lower than those obtained in Run 632-1A. The mist eliminator condition was unchanged, with less then 1 percent restriction at the end of the run. It had not been cleaned since the beginning of Run 629-1A, for a total of 916 operating hours.

7.2 LIME AND LIME/MgO TESTING WITH FLY-ASH-FREE FLUE GAS

The venturi/spray tower system was operated from June through October 1976 with fly-ash-free flue gas. Hot flue gas was withdrawn from the Boiler No. 10 gas duct at a point downstream from the electrostatic precipitator. After the precipitator, this flue gas normally contained 0.04 to 0.10 grain/dry scf of particulate matter.

Runs 634-1A through 638-1A were made with lime slurry, Run 718-1A with limestone slurry, and Runs 639-1A through 643-1A with lime slurry and added MgO (at 2000 ppm effective liquor magnesium ion concentration). These tests were conducted primarily to discover any significant differences in the scrubber system performance that might exist between scrubbing with fly-ash-free slurries and scrubbing with fly-ash-containing slurries. Major test conditions and selected results for lime runs without MgO addition are given in Table 7-2 and for lime runs with MgO addition in Table 7-3. An evaluation and discussion of each test is presented below.

Table 7-2

MAJOR TEST CONDITIONS AND SELECTED RESULTS OF VENTURI/SPRAY TOWER LIME TESTING WITH FLY-ASH-FREE FLUE GAS

Major Test Conditions (1)	634-1A	635-1A	636-1A	637-1A	638-1A
MgO addition	No	No	No	No	No
Fly ash	No	No	No	No	No
Gas rate, acfm	35,000	35,000	25,000	35,000	35,000
Spray tower liquor rate, gpm	1400	1400	1400	1400	1400
Venturi liquor rate, gpm	600	600	600	600	600
Percent solids recirculated	4	8	8	8	4
Effluent residence time, min	12	12	12	3.0	3.0
Scrubber inlet liquor pH (controlled)	8.0	8.0	8.0	8.0	8.0
Effective Mg^{++} concentration, ppm	0	0	0	0	0
Venturi pressure drop, in. H_2O	9	9	9	9	9
Number of spray headers	4	4	4	4	4
Selected Results					
On stream hours	319	190	164	137	174
Percent SO_2 removal	76	76	85	71	78
Inlet SO_2 concentration, ppm	2600	2550	2800	2950	2500
SO_2 make-per-pass, m-moles/liter	7.5	7.5	6.5	8.0	7.5
Scrubber inlet liquor $SO_3^=$ concentration, ppm (2)	70	100	75	92	110
Lime utilization, 100x moles SO_2 absorbed/mole Ca added	90	91	92	95	94
Scrubber inlet liquor percent gypsum saturation @ 50°C	100	95	85	80	120
Percent sulfite oxidation	10	20	17	15	17
Scaling	Cycling	V. Slight	No	No	Slight
Mist eliminator restriction, percent (3)	--	2	1	1	1

Notes:

1) Lime was added to the scrubber downcomer in all runs.
2) Total sulfite includes $SO_3^=$ and HSO_3^-.
3) The mist eliminator was not cleaned prior to each run.

Table 7-3

MAJOR TEST CONDITIONS AND SELECTED RESULTS OF VENTURI/SPRAY TOWER LIME TESTING WITH FLY-ASH-FREE FLUE GAS AND MgO ADDITION

Major Test Conditions[(1)]	639-1A	640-1A	641-1A	642-1A	643-1A
MgO addition	Yes	Yes	Yes	Yes	Yes
Fly ash	No	No	No	No	No
Gas rate, acfm	35,000	35,000	35,000	35,000	35,000
Spray tower liquor rate, gpm	1400	1400	1400	1050	1400
Venturi liquor rate, gpm	600	600	~140	~140	600
Percent solids recirculated	4	8	8	8	8
Effluent residence time, min	3.0	3.0	3.0	3.0	3.0
Scrubber inlet liquor pH (controlled)	7.0	7.0	7.0	7.0	7.0
Effective Mg^{++} concentration, ppm	2000	2000	2000	2000	2000
Venturi pressure drop, in. H_2O	9	9	3.5	3.5	9
Number of spray headers	4	4	4	3(2)	4
Selected Results					
On stream hours	183	157	120	249	191
Percent SO_2 removal	81	80	96	70	98
Inlet SO_2 concentration, ppm	2650	2950	2700	2650	2500
SO_2 make-per-pass, m-moles/liter	8.0	9.0	12.5	12.0	9.0
Scrubber inlet liquor $SO_3^=$ concentration, ppm(3)	270	180	1650	420	1110
Lime utilization, 100x moles SO_2 absorbed/mole Ca added	98	97	98	98	98
Scrubber inlet liquor percent gypsum saturation @ 50°C	105	85	6	45	10
Percent sulfite oxidation	28	24	11	14	18
Scaling	Yes	Cycling	No	No	No
Mist eliminator restriction, percent(4)	10	5	<1	3	1

Notes:

1) Lime was added to the scrubber downcomer and MgO dry fed to the effluent hold tank in all runs.
2) Run 642-1A was operated with the second spray header (from bottom) turned off.
3) Total sulfite includes $SO_3^=$ and HSO_3^-.
4) The mist eliminator was not cleaned prior to each run except Runs 640-1A and 641-1A.

7.2.1 Venturi/Spray Tower Fly-Ash-Free Lime Run 634-1A

The clarifier and scrubber had been cleaned before the start of Run 634-1A to purge the system of fly ash and magnesium ion. The major test conditions for the run are listed in Table 7-2. Other detailed operating conditions can be found in Appendix E.

Operating conditions for this run were identical to those for Run 626-1A (see Reference 3), except that the solids content in the recirculated slurry was 4 percent (no fly ash) for Run 634-1A and 8 percent (with fly ash) for Run 626-1A. Therefore, a direct comparison between the two runs can be made as to the effect of the fly ash:

	Run 626-1A	Run 634-1A
Percent solids recirculated	8 (with fly ash)	4 (no fly ash)
Percent SO_2 removal	78	76
Inlet SO_2 concentration, ppm	2500	2600
Inlet liquor $SO_3^{=}$ conc., ppm	80	70
Lime utilization, percent	85	90
Inlet liquor gypsum saturation, percent	100	100
Percent sulfite oxidation	22	10

The test results for these two runs are essentially the same except for the lower sulfite oxidation for Run 634-1A. Although the calculated average gypsum saturation in the scrubber inlet liquor was 100 percent for both runs, saturation ranged widely during both runs from 20 to 170 percent.

The scrubber was not inspected at the end of Run 634-1A. But there was no sign of an increase in pressure drop across the mist eliminator throughout the run to indicate any mist eliminator fouling.

7.2.2 Venturi/Spray Tower Fly-Ash-Free Limestone Run 718-1A

Run 718-1A was not originally scheduled in the venturi/spray tower fly-ash-free lime test block. Because of a temporary interruption of lime supply, the run had to be made with limestone slurry. The test was interrupted for about 2 days by an unscheduled Boiler No. 10 maintenance outage.

The test conditions for Run 718-1A were similar to those for Run 707-1A (see Reference 3) except that the solids content in the recirculated slurry was 8 percent (no fly ash) for Run 718-1A and 15 percent (with fly ash) for Run 707-1A (see Appendix E for other test conditions during 718-1A). A comparison of the test results from these two runs is given below:

	Run 707-1A	Run 718-1A
Percent solids recirculated	15 (with fly ash)	8 (no fly ash)
Percent SO_2 removal	82	77
Inlet SO_2 concentration, ppm	3450	2400
Scrubber inlet liquor pH	5.7	5.9
Inlet liquor $SO_3^=$ conc., ppm	140	110
Limestone utilization, percent	80	78
Inlet liquor gypsum saturation, percent	45	120
Percent sulfite oxidation	14	22
Percent solids in filter cake	66	56

In general, the scrubber performance during Run 718-1A was comparable to that of Run 707-1A, except that the sulfite oxidation averaged 22 percent and the gypsum saturation in the scrubber inlet liquor averaged 120 percent for Run 718-1A, compared with 14 percent oxidation and 45 percent saturation for Run 707-1A. In addition, the average scrubber inlet pH was 5.9 for Run 718-1A (no fly-ash) and 5.7 for Run 707-1A (with fly ash) at comparable limestone utilization. A notable difference between the two runs was the average solids content in the filter cake discharged from the system. The fly-ash-free filter cake from Run 718-1A averaged 56 percent solids, whereas the fly-ash-containing filter cake from Run 707-1A averaged 66 percent solids.

The mist eliminator was only 2 percent restricted at the end of Run 718-1A.

7.2.3 Venturi/Spray Tower Fly-Ash-Free Lime Run 635-1A

The test conditions for Run 635-1A were the same as for Run 634-1A except that the solids concentration in the recirculated slurry was increased from 4 to 8 percent to observe its effect on liquor gypsum saturation. The test was interrupted by a 35-hour Boiler No. 10 maintenance outage. The mist eliminator was not cleaned prior to the start of the run.

Average calculated gypsum saturation in the scrubber inlet liquor for Run 635-1A was 95 percent, as compared with 100 percent for Run 634-1A. Sulfite oxidation averaged 20 percent for Run 635-1A compared with 10 percent for Run 634-1A and 22 percent for Run 626-1A (with fly ash). The filter cake solids content averaged only 47 percent, notably lower than the 56 percent obtained during Run 626-1A when fly ash was present. Other test results during Runs 634-1A and 635-1A were essentially similar. The mist eliminator condition remained unchanged during Run 635-1A; at the end of the run, the mist eliminator was still 2 percent restricted.

7.2.4 Venturi/Spray Tower Fly-Ash-Free Lime Run 636-1A

The test conditions for Run 636-1A were the same as for Run 635-1A except that the flue gas flow rate was reduced from 35,000 to 25,000 acfm (spray tower gas velocity reduced from 9.4 to 6.7 ft/sec). This change resulted in liquid-to-gas ratios of 30 and 70 gal/Mcf in the venturi and spray tower, respectively, for Run 636-1A, compared with 21 and 50 gal/Mcf for Run 635-1A.

The purpose of Run 636-1A was to observe the effect of the higher liquid-to-gas ratios (lower gas flow rate) on the SO_2 removal and liquor gypsum saturation. The run was interrupted for 45 hours by a Boiler No. 10 outage. The mist eliminator was not cleaned prior to the run.

As expected from the higher liquid-to-gas ratios, the SO_2 removal averaged 85 percent at 2500 to 3100 ppm inlet SO_2 concentration for Run 636-1A, compared with 76 percent at 1900 to 3200 ppm for Run 635-1A. Average gypsum saturation in the scrubber inlet liquor was 85 percent for Run 636-1A, as opposed to 95 percent for Run 635-1A. Sulfite oxidation, lime utilization, and filter cake solids content were similar for these two runs. The restriction of the mist eliminator during Run 636-1A went from 2 percent at the beginning of the run to 1 percent at the end.

7.2.5 Venturi/Spray Tower Fly-Ash-Free Lime Runs 637-1A and 638-1A

Runs 637-1A and 638-1A were conducted to investigate the effect of lower effluent residence time on the liquor gypsum saturation.

The test conditions for Runs 637-1A and 638-1A were the same as for Runs 635-1A and 634-1A, respectively, except for the effluent residence times. The differences in the test conditions for these four runs were:

Run No.	Effluent Residence Time, min	Percent Solids Recirculated
634-1A	12	4
635-1A	12	8
637-1A	3	8
638-1A	3	4

Other operating conditions for these runs were identical.

In general, gypsum saturation increased with decreasing residence time and decreasing percent solids recirculated. Average calculated gypsum saturations in the scrubber inlet liquor were 80 and 120 percent, respectively, for Run 637-1A and 638-1A. Some minor scale was observed in the scrubber internals at the end of Run 638-1A. This was consistent with its 120 percent average saturation, the highest obtained for these runs. This level of saturation occurred under the most severe scale-forming operating conditions of the four test runs. The average SO_2 removal was about 76 percent for all four runs at an average inlet SO_2 concentration of 2600 ppm. Sulfite oxidation averaged 15 and 17 percent and lime utilization averaged 95 and 94 percent for Runs 637-1A and 638-1A, respectively. The filter cake solids concentrations were again lower than generally obtained with fly-ash-containing sludge. The average solids contents were 47 and 53 percent for Runs 637-1A and 638-1A, respectively.

The mist eliminator condition remained unchanged at 1 percent restriction throughout Runs 637-1A and 638-1A. The mist eliminator had not been cleaned since the beginning of Run 629-1A, for a total of 2134 hours of reliable operation.

7.2.6 Venturi/Spray Tower Fly-Ash-Free Lime/MgO Run 639-1A

Run 639-1A was the first fly ash-free lime run with MgO addition (see Table 7-3). MgO was dry fed to the effluent hold tank to maintain an effective magnesium ion concentration (i.e., excess over equivalent chloride ion concentration) of 2000 ppm in the scrubber liquor. The operating conditions chosen for Run 639-1A were the same as for Run 630-1A (see Section 7.1.2 and Appendix E), except that the solids concentration in the recirculated slurry was 4 percent (no fly ash) for Run 639-1A and 8 percent (with fly ash) for Run 630-1A. Therefore, a direct comparison in system performance could be made between the two runs. The mist eliminator was not cleaned prior to Run 639-1A.

Significant average results from Run 639-1A and 630-1A are tabulated below:

	Run 639-1A	Run 630-1A
Percent SO_2 removal	81	92
Inlet SO_2 conc., ppm	2650	3150
Percent sulfite oxidation	28	15
Inlet liquor gypsum saturation, percent	105	25
Inlet liquor $SO_3^=$ conc., ppm	270	770
Percent solids in filter cake	49	53

Again, the fly-ash-free sludge (Run 639-1A) had poorer dewatering characteristics and gave lower solids content in the filter cake. As can be seen, the scrubber performances were quite different between the two runs. Run 630-1A operated at a low 25 percent gypsum saturation whereas Run 639-1A was supersaturated. Sulfite oxidation for Run 630-1A was about one-half that of Run 639-1A. The scrubber inlet liquor sulfite concentration ($SO_3^=$ and HSO_3^-) was significantly higher for Run 630-1A, which probably contributed to the higher SO_2 removal for the run.

It was observed from these two runs and other subsequent runs that low liquor gypsum saturation was invariably accompanied by high liquor sulfite concentration, and the resultant high SO_2 removal, when MgO was added to the system.

Gypsum scaling occurred during Run 639-1A, and the mist eliminator was 10 percent restricted at the end of the run, mostly by gypsum sacle.

7.2.7 Venturi/Spray Tower Fly-Ash-Free Lime/MgO Run 640-1A

Run 640-1A was made under the same operating conditions as for Run 639-1A except that percent solids recirculated was raised from 4 to 8 percent to see if the gypsum scaling that occurred during Run 639-1A could be eliminated. The mist eliminator was cleaned prior to Run 640-1A.

Average gypsum saturation in the scrubber inlet liquor was 85 percent for Run 640-1A, compared with 105 percent for Run 639-1A. The gypsum scaling potential during Run 640-1A had in fact decreased, and this decrease was observed by a periodic inspection of a scale monitoring probe located at the bottom part of the spray tower. These inspections revealed that the scale deposit on the probe was cycling between the states of formation and dissolution throughout the run. Other test results for Runs 639-1A and 640-1A were similar. The mist eliminator was 5 percent restricted by scale at the end of Run 640-1A (157 operating hours), as opposed to 10 percent at the end of Run 639-1A (183 operating hours).

7.2.8 Venturi/Spray Tower Fly Ash-Free Lime/MgO Run 641-1A

Run 641-1A was made under the same conditions as existed in Run 640-1A, except the venturi throat was held wide open and the slurry flow rate to the venturi was set at 140 gpm (5 gal/Mcf liquid-to-gas ratio), the minimum controllable rate needed for flue gas cooling.

The purpose of Run 641-1A was to observe the effect of spray-tower-only operation on SO_2 removal, liquor gypsum saturation, and sulfite oxidation, in comparison with Run 640-1A. The mist eliminator was cleaned prior to the run.

Sulfite oxidation averaged only 11 percent for Run 641-1A, compared with 24 percent for Run 640-1A. The low oxidation during Run 641-1A might have contributed to the exceedingly low 6 percent gypsum saturation in the scrubber inlet liquor; gypsum saturation for Run 640-1A was 85 percent. Sulfite concentration ($SO_3^=$ and HSO_3^-) in the scrubber inlet liquor averaged 1650 ppm for Run 641-1A, in contrast with the low 180 ppm for Run 640-1A, and these two values were commensurate with the average SO_2 removals of 96 and 80 percent for Runs 641-1A and 640-1A, respectively. These results are consistent with those observed between Runs 639-1A and 630-1A (see Subsection 7.2.6).

The average filter cake solids contents and lime utilization were 48 and 98 percent for Run 641-1A and 49 and 97 percent for Run 640-1A. The mist eliminator was essentially clean, with less than 1 percent restriction at the end of Run 641-1A. Nearly all of the scale formed on the scrubber internals during the previous runs had disappeared by the end of the run.

7.2.9 Venturi/Spray Tower Fly Ash-Free Lime/MgO Run 642-1A

The operating conditions for Run 642-1A were the same as for Run 641-1A except that the spray tower slurry flow rate was reduced from 1400 to 1050 gpm (liquid-to-gas ratio reduced from 50 to 37 gal/Mcf) by turning off the second spray header from the bottom. The run was interrupted for about 1 day by a scheduled inspection of mechanical components by TVA.

Since Run 641-1A had achieved a very high SO_2 removal (96 percent) with spray-tower-only operation, Run 642-1A was made to observe whether a reduced spray tower slurry flow could still give a satisfactory SO_2 removal, and whether the low gypsum saturation could still be maintained. The mist eliminator was not cleaned prior to this run.

The average SO_2 removal for Run 642-1A dropped to 70 percent, compared with 96 percent for Run 641-1A, both at an average inlet SO_2 concentration of about 2700 ppm. Average sulfite oxidation for Run 642-1A increased slightly to 14 percent from 11 percent for Run 641-1A. Average gypsum saturation in the scrubber inlet liquor also increased during Run 642-1A to 45 percent from 6 percent for Run 641-1A. Liquor sulfite concentration in the scrubber inlet slurry decreased to 420 ppm for 642-1A, compared with 1650 ppm for Run 641-1A. There was a brief period of about 1 day (September 19-20) during Run 642-1A when gypsum saturation in the scrubber inlet liquor dropped to about 8 percent and scrubber inlet liquor sulfite concentration increased to about 1600 ppm for no apparent reason. The SO_2 removal during this period was about 90 percent at 2800 ppm average inlet SO_2 concentration.

Average lime utilization was 98 percent for both Runs 641-1A and 642-1A. The filter cake solids content was 51 percent for Run 642-1A, compared with 48 percent for Run 641-1A. The mist eliminator was 3 percent restricted by scale at the end of Run 642-1A.

7.2.10 Venturi/Spray Tower Fly-Ash-Free Lime/MgO Run 643-1A

Run 643-1A was made to provide fly-ash-free sludge to Aerospace Corporation for sludge disposal studies. The operating conditions chosen for Run 643-1A were identical to those for Run 640-1A except that the rotary drum vacuum filter was replaced by the centrifuge, so that the cake discharge belt could be used to load sludge into concrete mixing trucks. The mist eliminator was not cleaned prior to the run.

The test results from Runs 643-1A and 640-1A were markedly different under seemingly identical conditions. Average sulfite oxidation was 18 percent for Run 643-1A versus 24 percent for Run 640-1A. Average gypsum saturation in the scrubber inlet liquor was only 10 percent for Run 643-1A, compared with 85 percent for Run 640-1A. The low gypsum saturation during Run 643-1A was again accompanied by high 98 percent SO_2 removal (80 percent for Run 640-1A) and high 1110 ppm scrubber inlet liquor sulfite concentration (180 ppm for Run 640-1A), as had been observed in some of the earlier runs. The mist eliminator restriction during Run 643-1A decreased to 1 percent from 3 percent at the start of the run.

7.3 CONCLUSIONS

7.3.1 Lime/MgO Testing with Flue Gas Containing Fly Ash

Five test runs (Runs 629-1A through 633-1A) were made on the venturi/spray tower system using lime slurry with added MgO. The flue gas contained fly ash which comprised about 40 percent of total dry solids discharged from the system. The following conclusions were made from the results obtained during these runs:

- Better percent SO_2 removal can be obtained by increasing the magnesium ion concentration in the scrubbing liquor. At 2000 ppm effective magnesium ion concentration, the SO_2 removal improved by 15 to 20 percentage points
- The optimum scrubber inlet pH is in the range of 7 to 8. Operation below a pH of 7 decreases sulfite and bicarbonate concentrations available as scrubbing species. (Operation at a pH higher than 8 should reduce the magnesium solubility and consequently reduce the magnesium utilization.)
- The mist eliminator reliability with lime slurry (high utilization) operation was not affected by the presence of magnesium ions at the gypsum saturation levels encountered during these runs (15 to 75 percent)

7.3.2 Lime and Lime/MgO Testing with Fly-Ash-Free Flue Gas

Eleven test runs were made on the venturi/spray tower system during the fly-ash-free flue gas test block. Run 718-1A was the only run made with limestone slurry. Runs 634-1A through 638-1A were tested with lime slurry, and Runs 639-1A through 643-1A with lime slurry and MgO. The following conclusions were made from the results obtained during these runs:

- At a controlled scrubber inlet pH of 8 and with no added MgO, lime utilization for the fly-ash-free tests (Runs 634-1A through 638-1A) averaged about 93 percent, compared with about 88 percent for runs made with fly ash (see References 2 and 3) under similar test conditions
- The filter cake solids contents from the fly-ash-free runs were 5 to 10 weight percent lower than those from the corresponding runs with fly ash (see also Section 17.2.2)
- The total dissolved solids concentrations, particularly chloride species, were higher for the fly-ash-free runs than for the runs with fly ash because of the tighter water balance resulting from the reduced waste solids discharge
- Adding MgO (at 2000 ppm effective magnesium) does not always result in gypsum subsaturated operation. Conditions required to achieve consistent subsaturated operation have not yet been defined. However, when low gypsum saturation was obtained, it was consistently accompanied by high liquor sulfite concentration and high percent SO_2 removal
- Lower sulfite oxidation generally resulted in lower gypsum saturation
- At the 2000 ppm effective magnesium ion concentration level tested, gypsum scaling occurred at scrubber inlet gypsum saturation as low as 80 percent, compared with about 120 percent when no MgO was added. The equilibrium calcium ion concentration is lower when magnesium ion is present.

With a low calcium ion concentration in the scrubber inlet, the percentage increase in calcium ion concentration across the scrubber is greater (because of dissolution of lime, limestone, calcium sulfite, or all three), causing a greater percentage increase in gypsum saturation across the scrubber

Section 8

FLUE GAS CHARACTERIZATION

The Flue Gas Characterization Program was developed to answer a number of questions concerning the flue gas emissions at Shawnee. First, new data were needed to confirm or deny the validity of the existing mass loading data since quality control for these data had been poor. Second, the question was raised whether scrubbers generate particulates through reaction product entrainment, especially in the fine ($<2\mu$) particulate range. And third, owing to concern over the health hazards of sulfates, it was desired to determine the effect of scrubbers on sulfuric acid vapor (SO_3) emissions and use these data to estimate total sulfur emissions (i. e., SO_2, SO_3, and reaction product sulfates).

To allow testing for a long period under a variety of operating conditions as opposed to short term measurements by an outside group, it was decided to train onsite personnel to conduct the tests. Through a separate contract with the EPA, TRW Corporation was chosen to determine the best testing methods for size distribution and SO_3 measurement, and in conjunction with Bechtel and TVA to write the appropriate manuals, make the equipment operational and train personnel.

Initial intensive test series on both the venturi/spray tower and TCA systems were designed to determine the effect of major operating variables on mass removal, particulate size distribution, and SO_3 removal.

Variables investigated on the venturi/spray tower system were gas rate, slurry rate, MgO addition, venturi pressure drop, mist eliminator configuration, and percent solids recirculated. For one run, flue gas feed to the scrubber was obtained downstream from the electrostatic precipitator (ESP) to check scrubber performance on flue gas with low fly ash grain loadings. Flue gas feed for all other runs was obtained upstream of the fly ash collecting equipment. Included in Table 8-1 are the run conditions for the venturi/spray tower system tests. Testing on this unit was completed during the current reporting period; results are presented in Subsection 8.3 of this report.

Variables to be investigated on the TCA system are gas rate, liquor rate, MgO addition, and mist eliminator wash scheme. A fly-ash-free run will also be included.

8.1 SAMPLING LOCATIONS

Sampling was performed simultaneously at the inlet and outlet duct of each scrubber system. The ductwork at these locations is 40 inches

Table 8-1

MASS LOADING AND SO_3 CONCENTRATIONS DURING VENTURI/SPRAY TOWER TESTING

Controlled Variables	VFG-1A	VFG-1B		VFG-1C	VFG-1D	VFG-1E	VFG-1F	VFG-1G	VFG-1I	VFG-1P
Gas Rate, acfm @ 330°F	35,000	35,000	35,000	35,000	20,000	35,000	35,000	35,000	35,000	35,000
ST Gas Velocity, ft/sec	9.4	9.4	9.4	9.4	5.4	9.4	9.4	9.4	9.4	9.4
ST Slurry Rate, gpm	1,400	1,400	1,400	1,400	1,400	1,400	0	1,400	1,400	1,400
Venturi Slurry Rate, gpm	600	600	600	600	600	375	600	600	600	140
Venturi ΔP, in. H_2O	9	9	9	9	9	4.5 - 6.0	9	9	9	2.8 - 3.2
Percent Solids Recirculated	8	8	8	8	8	8	8	8	15	8
Fly Ash Loading	High	Low	Low	High	High	High	High	High	High	High
Alkali	Lime	Lime	Lime	Lime	Lime	Lime	Lime	Lime	Lime	Lime
Mist Elim. Configuration	chevron	chevron	chevron	chevron	chevron	chevron	chevron	chevron + York	chevron	chevron
Mist Elim. Wash Scheme(1)	LI	LI	LI	LI	LI	LI	LI	LI	LI	LI
MgO Addition	Yes	No	No	No	No	No	No	No	No	No
Uncontrolled Variables										
Gas Vel. at Mist Elim., ft/sec	9.4	9.4	9.4	9.4	5.4	9.4	9.4	9.4	9.4	9.4
System ΔP Range, in. H_2O	13.3 - 13.8	13.1 - 13.8	13.6 - 14.0	13.7 - 14.3	10.2 - 10.8	9.5 - 10.5	12.5 - 13.2	14.1 - 15.5	13.7 - 14.3	6.9 - 7.3
Total Dissolved Solids, ppm	13,200 - 18,000	2,500 - 5,200	7,000 - 9,500	7,700 - 9,600	6,000 - 8,800	5,400 - 8,000	7,200 - 10,000	8,300 - 9,400	6,600 - 9,000	6,900 - 8,100
Flue Gas Measurements										
Mass Loading Inlet										
Average, grains/dry scf	4.41	0.070	0.367	6.17	4.53	5.11	5.14	6.05	5.18	5.63
Range, grains/dry scf	3.66 - 5.50	0.039 - 0.096	0.118 - 0.609	4.82 - 8.39	3.68 - 5.78	3.77 - 7.90	3.72 - 6.41	3.90 - 8.76	3.70 - 6.05	5.13 - 6.66
Mass Loading Outlet										
Average, grains/dry scf	0.032	0.005	0.005	0.019	0.026	0.028	0.027	0.021	0.026	0.036
Range, grains/dry scf	0.023 - 0.046	0.003 - 0.007	0.003 - 0.009	0.013 - 0.023	0.018 - 0.039	0.020 - 0.037	0.022 - 0.037	0.018 - 0.024	0.017 - 0.037	0.031 - 0.040
Mass Loading Removal										
Average, %	99.3	92.0	98.3	99.7	99.4	99.4	99.5	99.6	99.5	99.4
Range, %	99.0 - 99.4	82.1 - 96.3	99.5 - 99.3	99.5 - 99.8	99.1 - 99.6	99.1 - 99.7	99.4 - 99.6	99.4 - 99.8	99.4 - 99.7	99.3 - 99.5
SO_3 Inlet										
Average, ppm	10.9	2.6	5.4	8.9	9.3	15.4	2.1	8.9	10.7	6.0
Range, ppm	3.4 - 14.8	1.7 - 3.7	3.6 - 7.2	3.0 - 17.1	4.5 - 13.5	7.1 - 24.8	0.4 - 4.5	2.5 - 15.8	5.8 - 21.2	4.1 - 7.8
SO_3 Outlet										
Average, ppm	2.9	0.9	2.7	3.6	4.1	8.9	0.3	4.1	3.5	1.7
Range, ppm	0.1 - 5.2	0.5 - 1.5	1.6 - 4.1	0.3 - 8.3	0.4 - 7.6	3.2 - 13.9	0.0 - 0.9	2.8 - 5.3	0.5 - 10.9	1.1 - 2.3
SO_3 Removal										
Average, %	74.9	67.3	50.9	62.2	53.9	--	71.0	66.9	72.5	64.9
Range, %	54.9 - 99.2	47.1 - 81.5	39.3 - 64.3	27.2 - 97.1	37.5 - 65.5	--	25.0 - 100.0	66.7 - 67.1	46.8 - 91.4	43.9 - 85.9
Test Philosophy	MgO add'n.	Low inlet fly ash loading.		Basic operating conditions.	Low gas rate.	Minimum venturi.	Venturi only.	Basic operating conditions. York demister added.	High percent solids recirculated.	Repeat of Run VFG-1E at correct conditions.
Comments		TDS low due to non-equilibration of clarifier.	TDS raised by $CaCl_2$ add'n. Boiler upset conditions caused higher inlet grain loading.			Flowmeter probs caused high flow to venturi. Desired 140 gpm. SO_3 values not simultaneous due to equip probs, no removals calculated.		Demister plugged after 55 hrs. of operation.		

in diameter. For those runs requiring traverses (mass loading and size distribution), two 8-point traverses at right angles to each other were performed. The sample ports are located ahead of the saturation sprays at the inlet (where the gas temperature is approximately 300°F-330°F) and after the reheater at the scrubber outlet (gas temperature approximately 250° F). The ports are also about two duct diameters upstream and six duct diameters downstream from the nearest obstruction.

8.2 TEST METHODS

8.2.1 Mass Loading

The procedure used at Shawnee for particulate mass loading measurement is a modification of EPA Method Five (see Reference 16). The equipment consists of a Hi-volume sampling train manufactured by the Aerotherm Division of Acurex Corporation. The major differences in test conditions between Shawnee and the typical Method Five application are: (1) the sampling flow rate at Shawnee was greater (2 cfm versus 0.75 cfm typical for EPA Method Five), (2) the filter temperatures were in the 350°F to 400°F range to prevent acid (SO_3) condensation, and (3) the first two impingers were filled with $NaCO_3$ solution to remove SO_2 and provide corrosion protection for the pump and dry gas meter. None of these changes should affect the accuracy of the method.

8.2.2 Size Distribution*

Size distribution measurements were made using out-of-stack heated inertial impactors. A Brink model BMS-11 impactor was employed for inlet sampling and a Meteorology Research, Inc., (MRI) Model 1502 was used for outlet sampling.

Figures 8-1 and 8-2 are drawings of the Brink and MRI sampling set-ups. The Brink impactor, modified to accept a specially designed internal cyclone, provides aerodynamic size distribution information between 0.3 and 10 microns in six distinct cuts. The MRI impactor measures aerodynamic size distribution between 0.3 and 30 microns, also in six cuts. Volumetric flow rate was typically 0.07 to 0.08 acfm for the Brink unit and 0.50 to 0.60 acfm for the MRI. Inlet and outlet sampling was concurrent, but sampling duration was not the same because of the large differences in the grain loadings. Plates greased with Apiezon H (Dow Corning) were used as impaction surfaces in both impactors.

To obtain representative size distribution measurements, sampling was performed by making sampling traverses indentical to the mass loading tests. The flow rate through the impactor was held constant

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* Size distribution and SO_3 measurement techniques are covered only briefly here. A more complete discussion can be found in Reference 17.

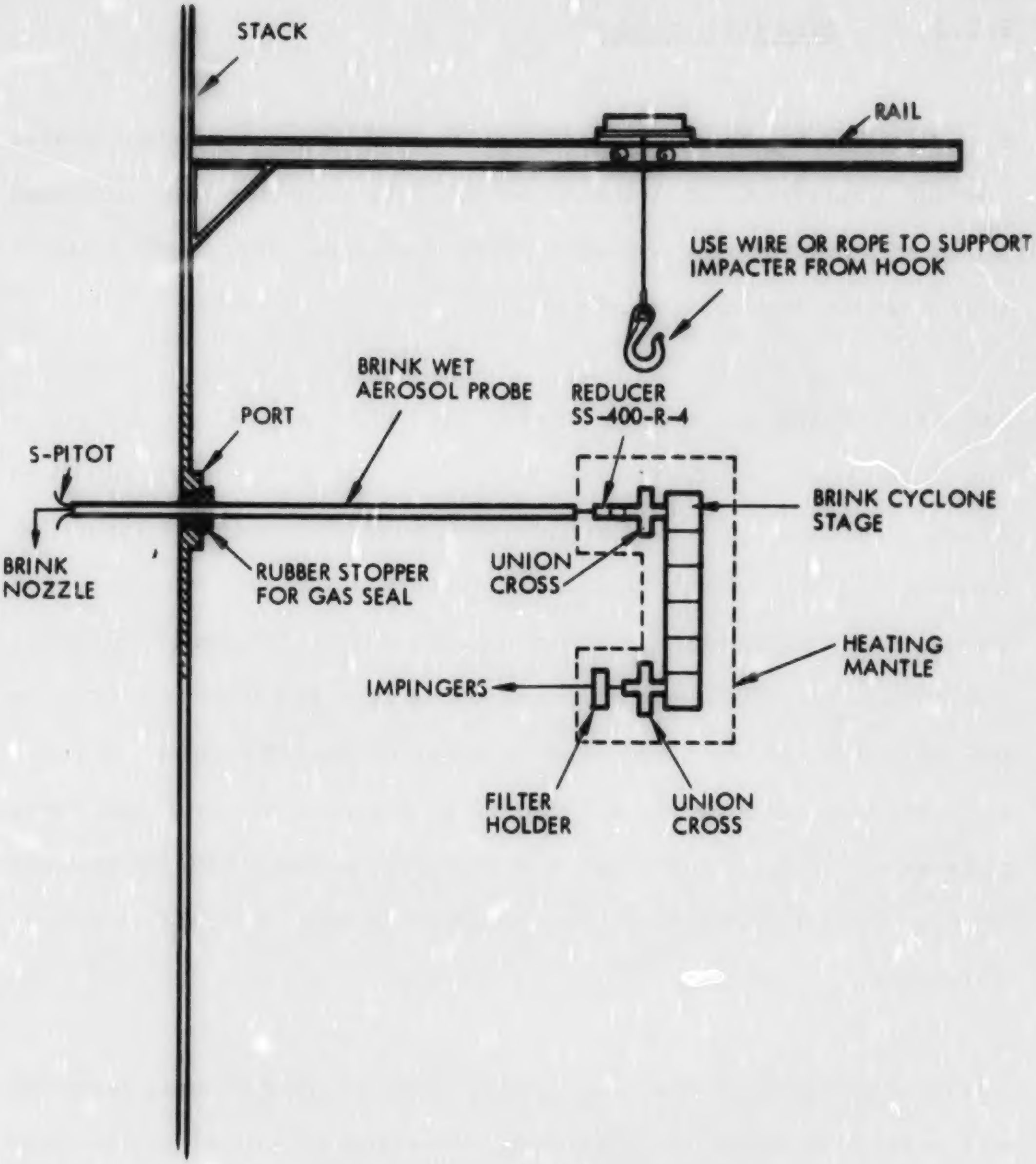
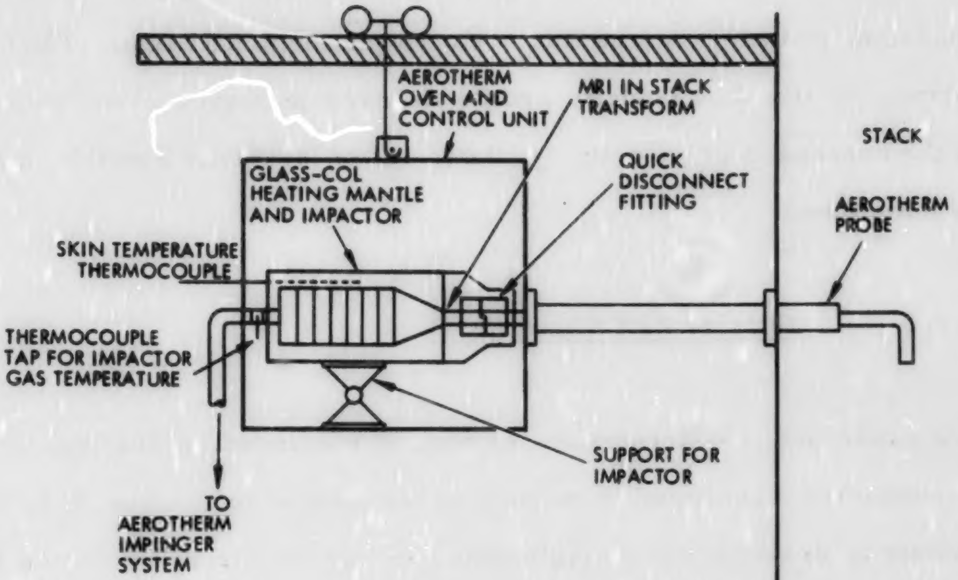


Figure 8-1. Brink Impactor



AEROTHERM OVEN AND CONTROL UNIT
MRI IN STACK TRANSFORM
STACK
GLASS-COL HEATING MANTLE AND IMPACTOR
QUICK DISCONNECT FITTING
AEROTHERM PROBE
SKIN TEMPERATURE THERMOCOUPLE
THERMOCOUPLE TAP FOR IMPACTOR GAS TEMPERATURE
SUPPORT FOR IMPACTOR
TO AEROTHERM IMPINGER SYSTEM
GAS FLOW

Figure 8-2. MRI Site Set-up

to ensure constant impactor stage cut sizes. The sampling nozzle was chosen to provide average duct velocity at the nozzle inlet. The uniformity of the duct velocity profile assured that even when sampling at the average duct velocity, ± 10 percent of isokinetic sampling could be maintained.

8.2.3 Sulfuric Acid Vapor (SO_3)

The vapor phase concentration of SO_3 is measured at Shawnee using a controlled condensation technique, as shown in Figure 8-3. The sample is drawn from a single point approximately 1 foot inside the stack. The sampled gas is cooled by means of a modified Graham condenser until essentially all the SO_3 condenses, but the temperature of the gas is kept above the water dew point to prevent any interference from SO_2 while a heated quartz filter system removes particulate matter. The condensed acid is then titrated with NaOH, using bromphenol blue as the indicator.

8.3 TEST RESULTS FOR VENTURI/SPRAY TOWER SYSTEM

8.3.1 Mass Loading

Table 8-1 gives the run conditions and results of the mass loading and SO_3 tests recently completed on the venturi/ spray tower system.

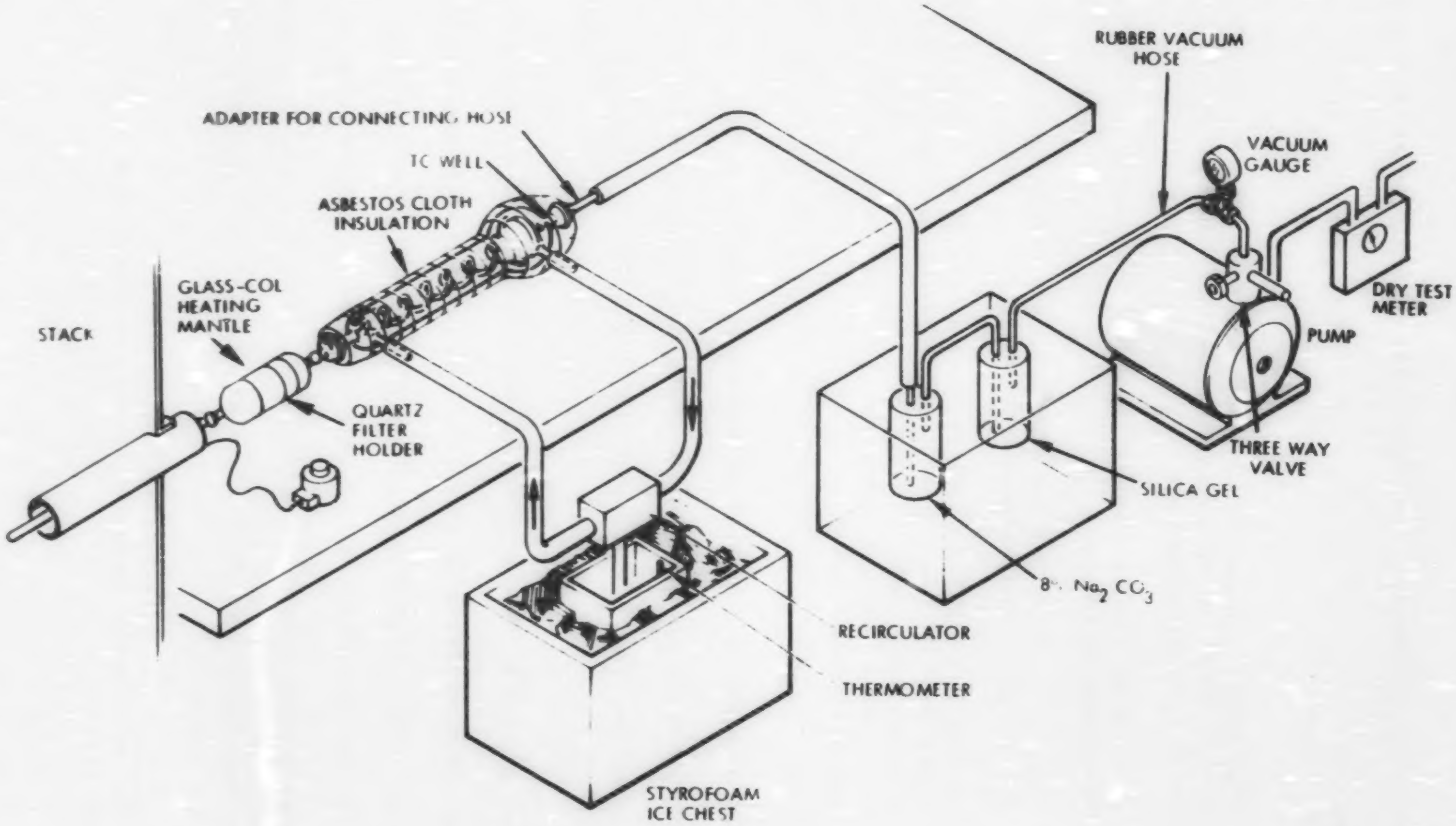


Figure 8-3. Controlled Condensation System Set-up

Four conclusions concerning the mass loading tests are readily apparent:

- The outlet values are all below the EPA New Source Performance Standard of approximately 0.055 grain/dry scf (60 °F) at 30 percent excess air
- The outlet values appear relatively unaffected by changes in operating condition
- The range of values for the new data is more consistent than for the previously reported data*
- During Run VFG-1B, where the flue gas feed was downstream from the ESP (i.e., low fly ash content), particulate emission ranged from 0.003 to 0.009 grain/dry scf, indicating that emission of scrubber reaction products for this system could not exceed this value

To further quantify the amount of entrained reaction products emitted from the scrubber, the particulate from one outlet mass loading filter was analyzed for each of Runs VFG-1A, VFG-1B, and VFG-1C.

Table 8-2 presents the results of wet-chemical and semiquantitative spectrographic analyses of these solids. If it is assumed that all the calcium and magnesium in the samples were present as hydrated reaction products (as noted in Table 8-2), an entrained reaction product mass loading can be calculated. For the run VFG-1B analysis, the resultant value was 0.002 grain/dry scf; for the VFG-1A and

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* For the previously reported data, see Reference 1, pages 11-1 through 11-14.

Table 8-2

ANALYSES OF OUTLET FILTERS

Specie	VFG-1A			VFG-1B			VFG-1C		
	TVA Lab	Bechtel Lab[(1)]		TVA Lab	Bechtel Lab[(1)]		TVA Lab	Bechtel Lab[(1)]	
		1	2		1	2		1	2
Ca, wt. %	7.4	3.7	5.4	6.6	10.0	10.4	3.7	4.0	7.4
Mg, wt. %	0.4	1.3	0.4	0.3	3.6	1.0	0.2	1.4	0.6
Fe, wt. %	6.2	5.2	9.1	7.1	3.1	5.8	4.6	3.1	6.0
Al, wt. %	1.9	2.0	5.9	1.1	1.1	3.1	2.9	3.4	9.1
Total Sulfur, wt. %	13.5	9.8	--	15.3	11.7	--	12.0	10.3	--
Reaction Products Calculated wt. % (2)	32.5	22.5	24.4	28.6	61.3	48.2	16.2	24.4	33.6
Calculated Grain Loading, gr/Dscf	0.008	0.005	0.006	0.001	0.003	0.002	0.003	0.005	0.007

Notes: (1) Two methods were used: 1 = wet chemical methods and 2 = semi-quantitative spectrographic.

(2) Assumes: $Ca \equiv CaSO_3 \cdot 1/2H_2O + CaSO_4 \cdot 2H_2O$ such that oxidation is 20 percent and all MgO was converted to $MgSO_4 \cdot 7H_2O$

VFG-1C analysis, the value was approximately 0.006 grain/dry scf. However, since the runs were made at the same operating conditions (see Table 8-1), the entrainment values should be the same. The values for Runs VFG-1A and VFG-1C appear high, probably because a large portion of the calcium collected from these runs existed in the fly ash emitted from the scrubber and should not have been included in the reaction product emission estimation. Scanning electron microscope (SEM) photographs were taken of the outlet mass loading filter and observation of these photographs indicated that the solids were small spherical fly ash particles. Chemical analysis of the solids by x-ray will be performed and reported at a later date.

8.3.2 Sulfuric Acid Vapor (SO_3)

SO_3 measurements on the venturi/spray tower system (see Table 8-1) indicate that percent SO_3 removal is independent of operating variable level and inlet SO_3 concentration. When SO_3 inlet concentration was plotted against SO_3 outlet concentration for all the data from all the runs (see Figure 8-4), the best curve fit was a straight line with a slope of 0.42 (corresponding to a constant removal of 58 percent) and a standard error of 1.49 ppm of SO_3.

Considering the small quantity being measured and the resulting uncertainty of the accuracy, the data appear to be quite consistent.

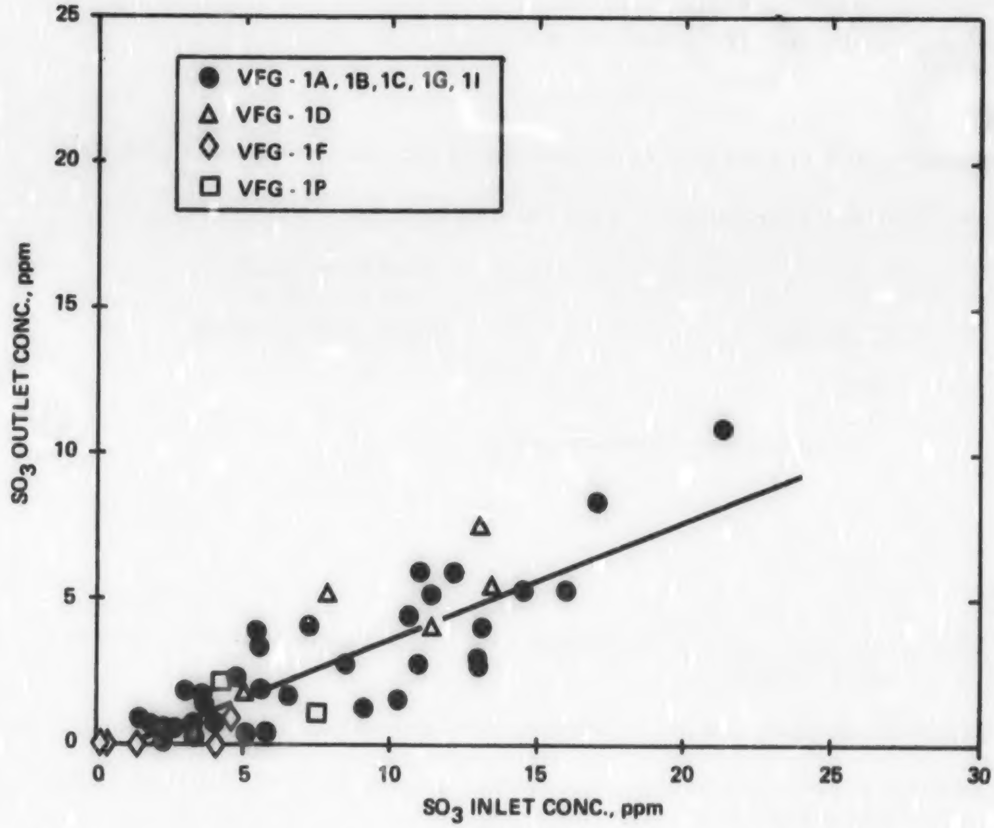

Figure 8-4. SO_3 Inlet Versus Outlet Concentration for All Runs

Emission concentration ranged from zero to 13.8 ppm. The significance of these values relative to the SO_3 ultimately existing in the ambient environment depends on the percentage of the emitted SO_2 that is oxidized. In any event, the fact that outlet SO_3 concentrations were always below inlet concentrations shows that the scrubbing process does not contribute to SO_3 emissions.

An estimate of the relative contribution of SO_3 to the total sulfur discharged into the atmosphere is as follows:

Component	Mole percent of the total Sulfur Discharged
SO_2	97.7
SO_3	2.2
Scrubber reaction products	0.1
	100.0

Basis:

SO_2 - 600 ppm outlet (equivalent to 80 percent removal at 3000 ppm inlet)

SO_3 - 13.8 ppm outlet (maximum value measured)

Scrubber reaction products - 0.0045 grain/dry scf (highest value estimated from Run VFG-1B)

Laboratory tests conducted by TRW have indicated that passage of the flue gas through the particulate collected on the filter used ahead of the condensing coil can reduce the measured SO_3 as much as 12 percent for the scrubber inlet SO_3 measurements. The removal mechanism is presumed to be due to alkalinity in the fly ash. Because of the much smaller amount of fly ash in the outlet, it is believed that the scrubber outlet SO_3 would be unaffected. No attempt was made to correct the inlet values since the laboratory-determined correction value is only approximate. The presence of condensed HCl would interfere with the measurement since the acid/base titration would not make a distinction between the two acids. Under our sampling conditions HCl should not be removed; however, as a check, the samples were analyzed for chloride. None was found.

8.3.3 Size Distribution

Values of the inlet and outlet grain loadings for each run as a function of particle size are plotted in Figures 8-5 through 8-14*. Inlet and outlet grain loadings as a function of size using geometric mean values of all the measurements for each run are plotted for runs with fly ash in Figure 8-15 and for the run with low fly ash in Figure 8-16. The outlet particulate size distributions, like the mass loading results, appear to be fairly independent of operating variable level for the runs with flue gas taken directly from the boiler. The run with low fly ash (Run VFG-1B) exhibits a similar shape but lower values due to the reduced grain laoding.

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* These values are calculated from the raw impactor data using the method described in Reference 18.

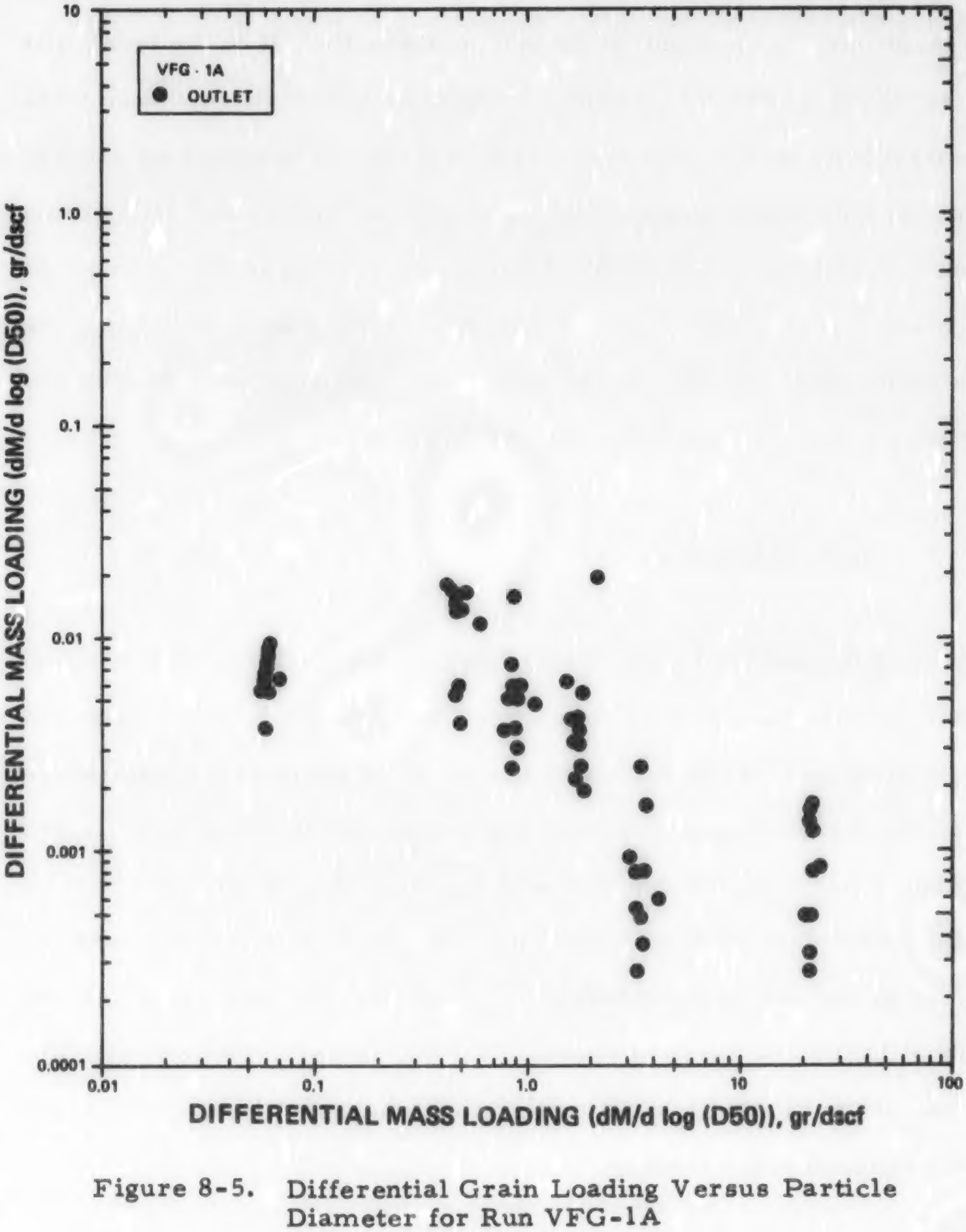

Figure 8-5. Differential Grain Loading Versus Particle Diameter for Run VFG-1A

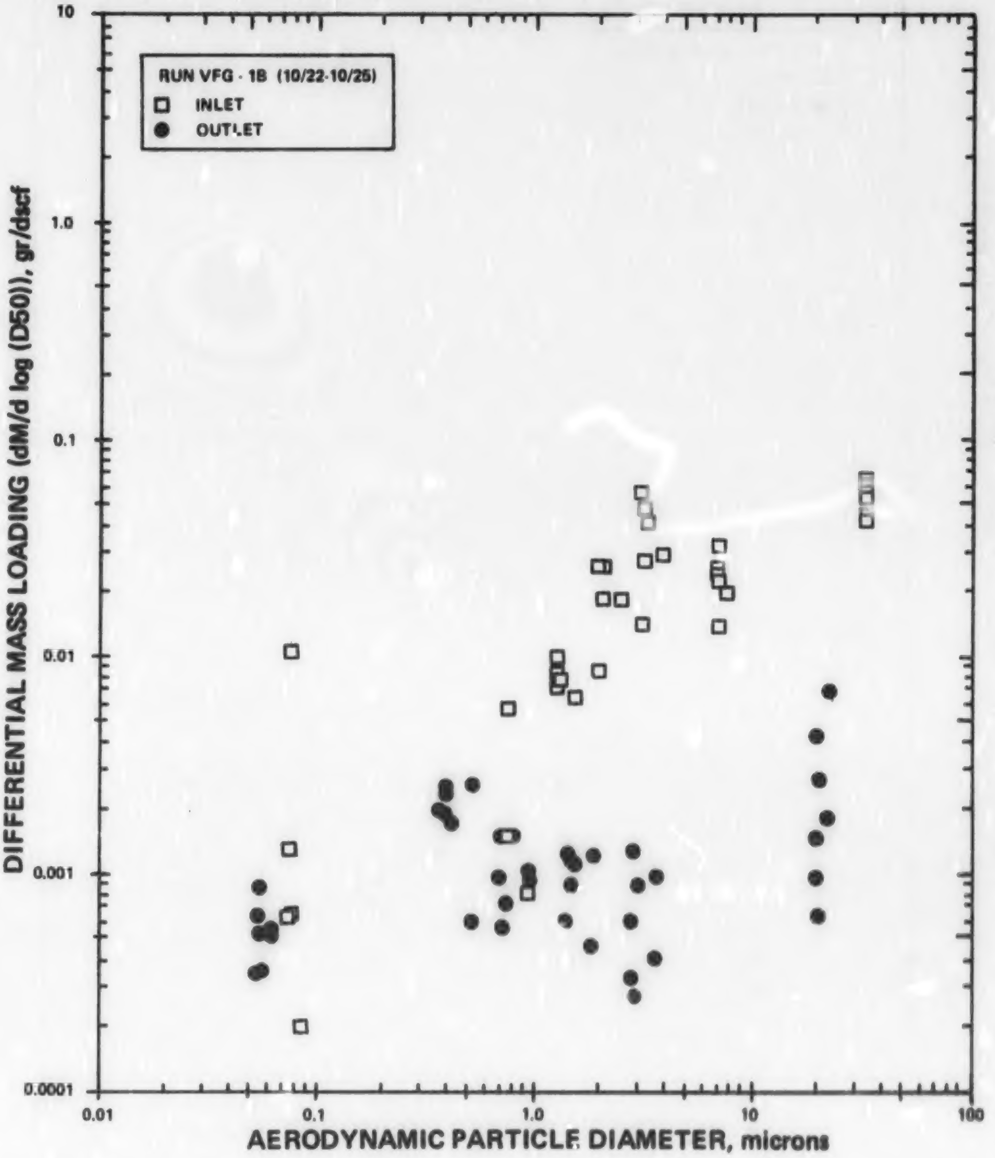

Figure 8-6. Differential Grain Loading Versus Particle Diameter for Run VFG-1B (10/22/76 - 10/25/76)

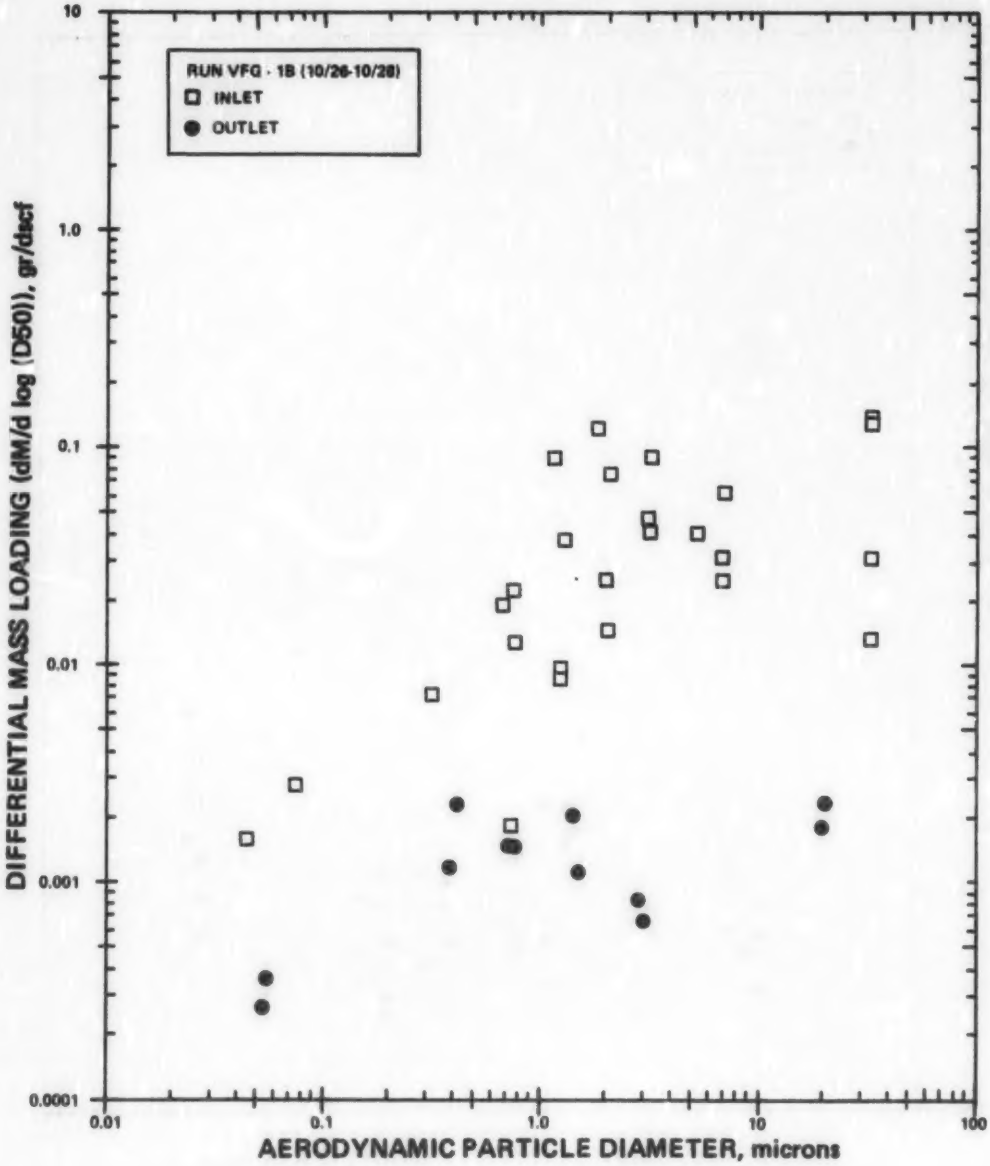

Figure 8-7. Differential Grain Loading Versus Particle Diameter for Run VFG-1B (10/26/76 - 10/28/76)

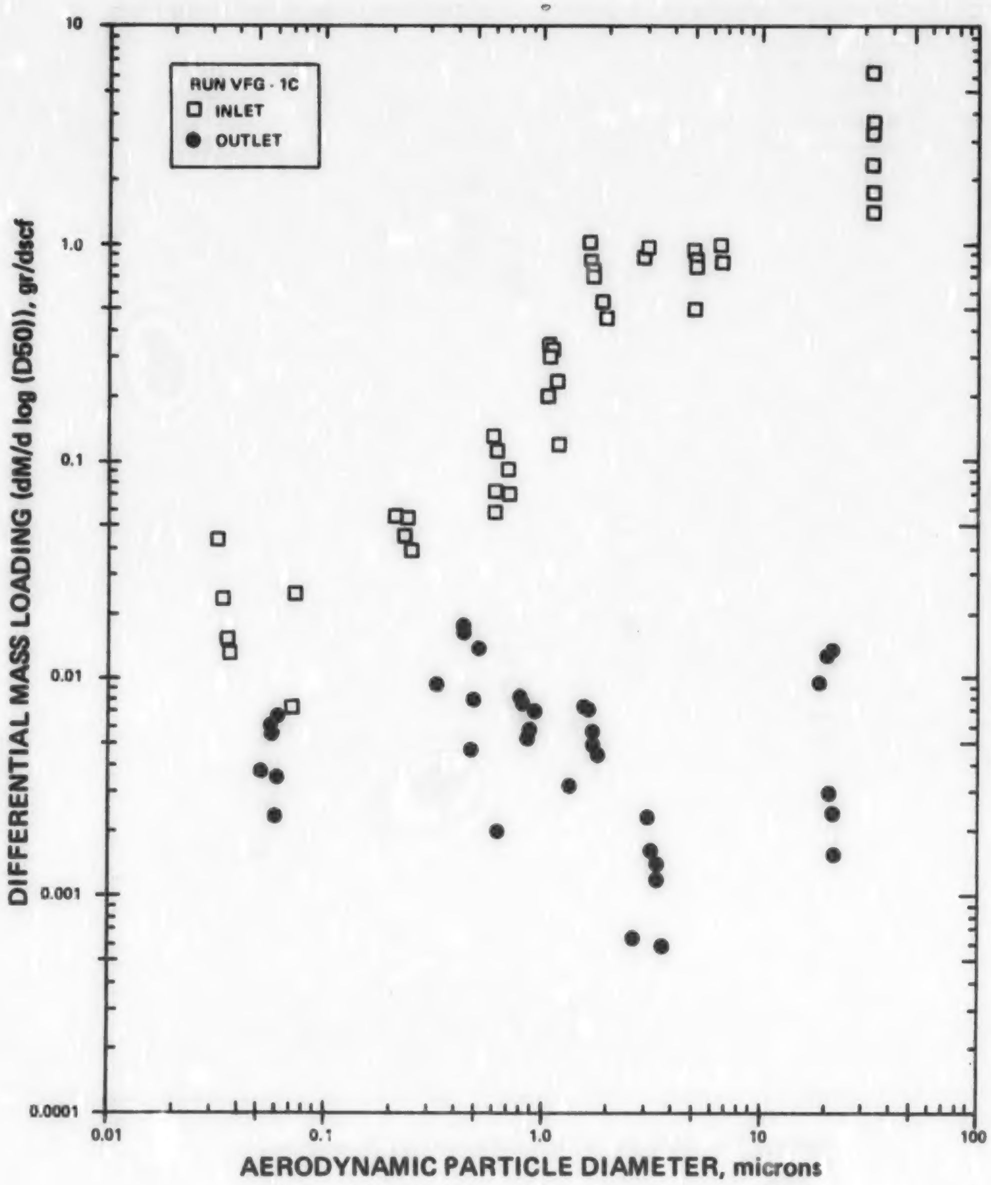

Figure 8-8. Differential Grain Loading Versus Particle Diameter for Run VFG-1C

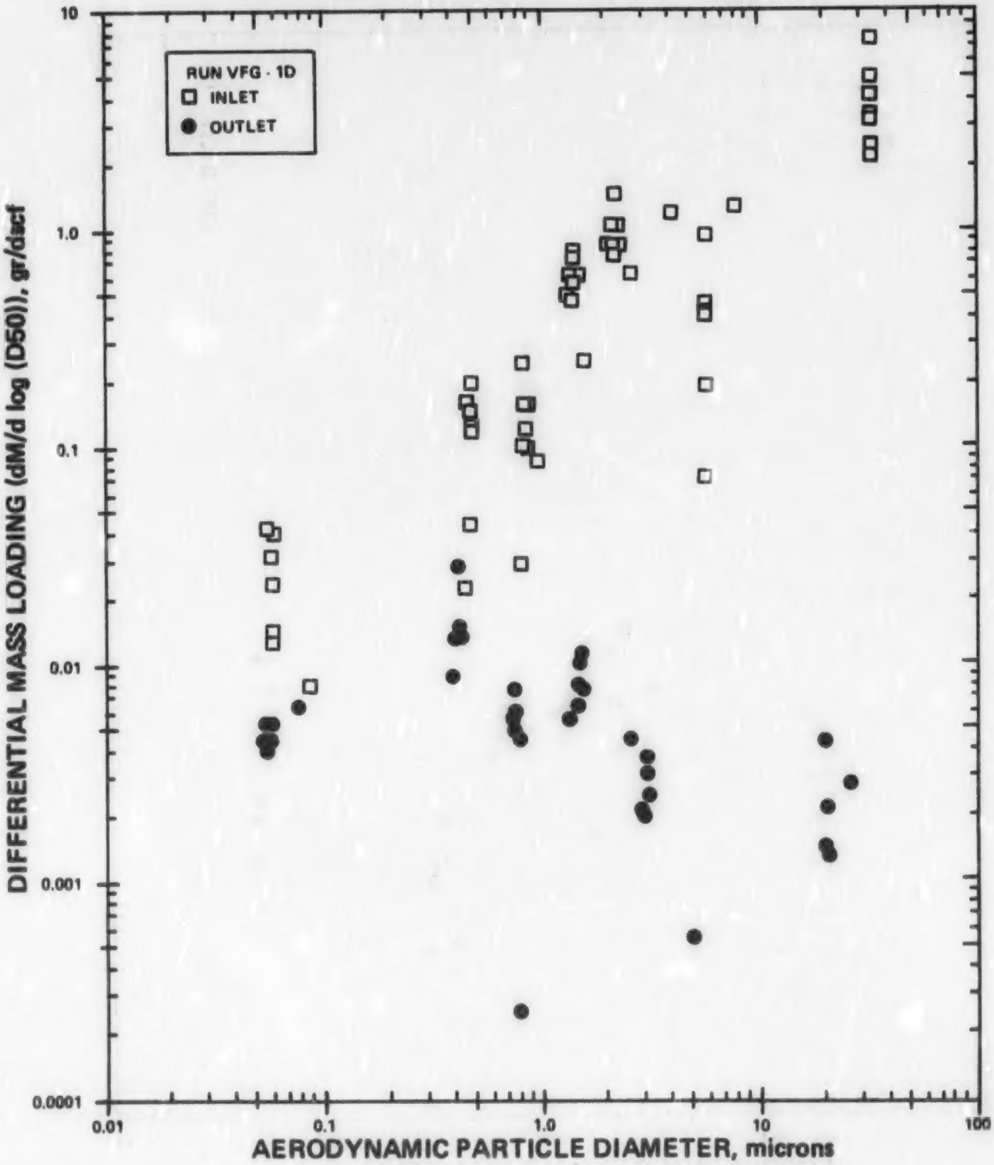

Figure 8-9. Differential Grain Loading Versus Particle Diameter for Run VFG-1D

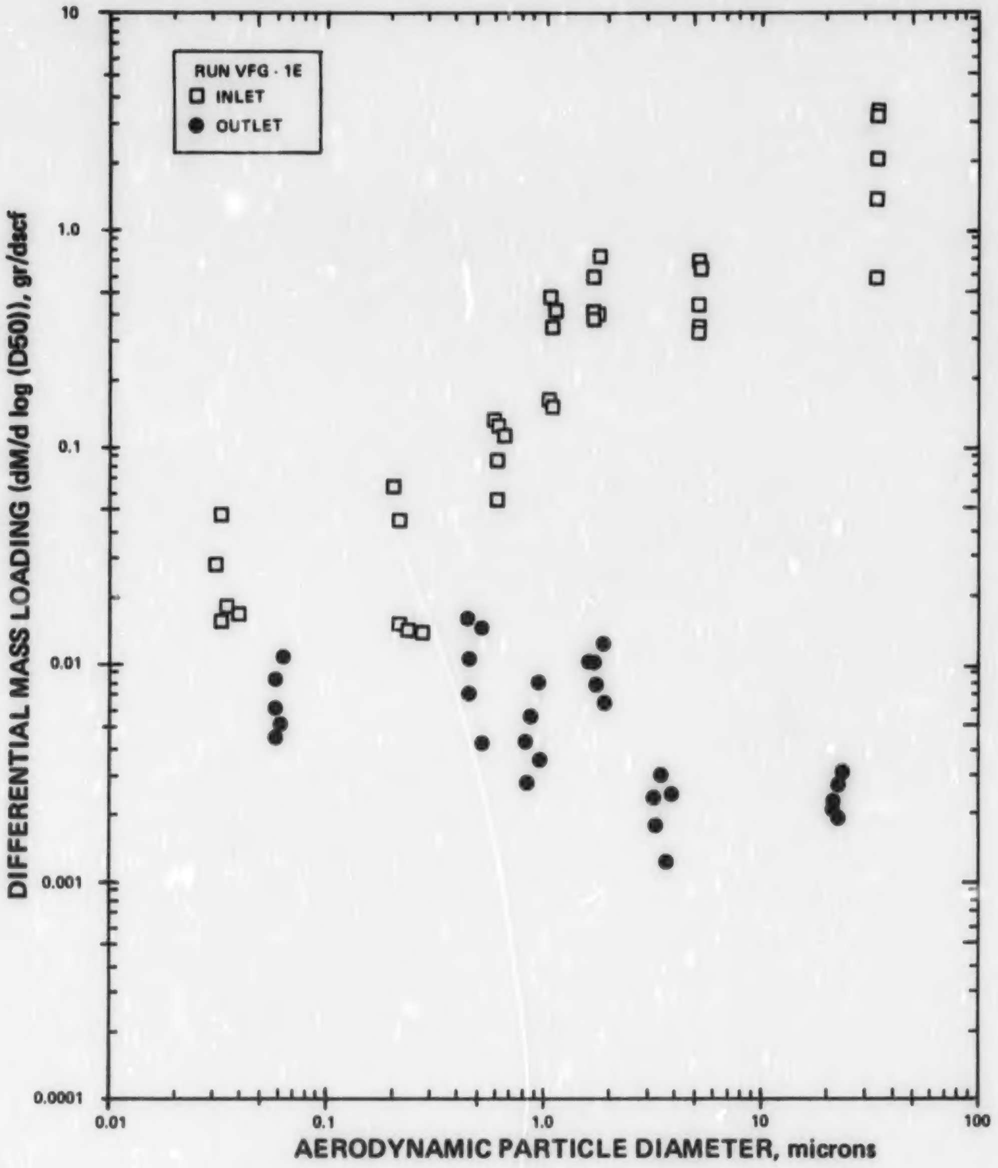

Figure 8-10. Differential Grain Loading Versus Particle Diameter for Run VFG-1E

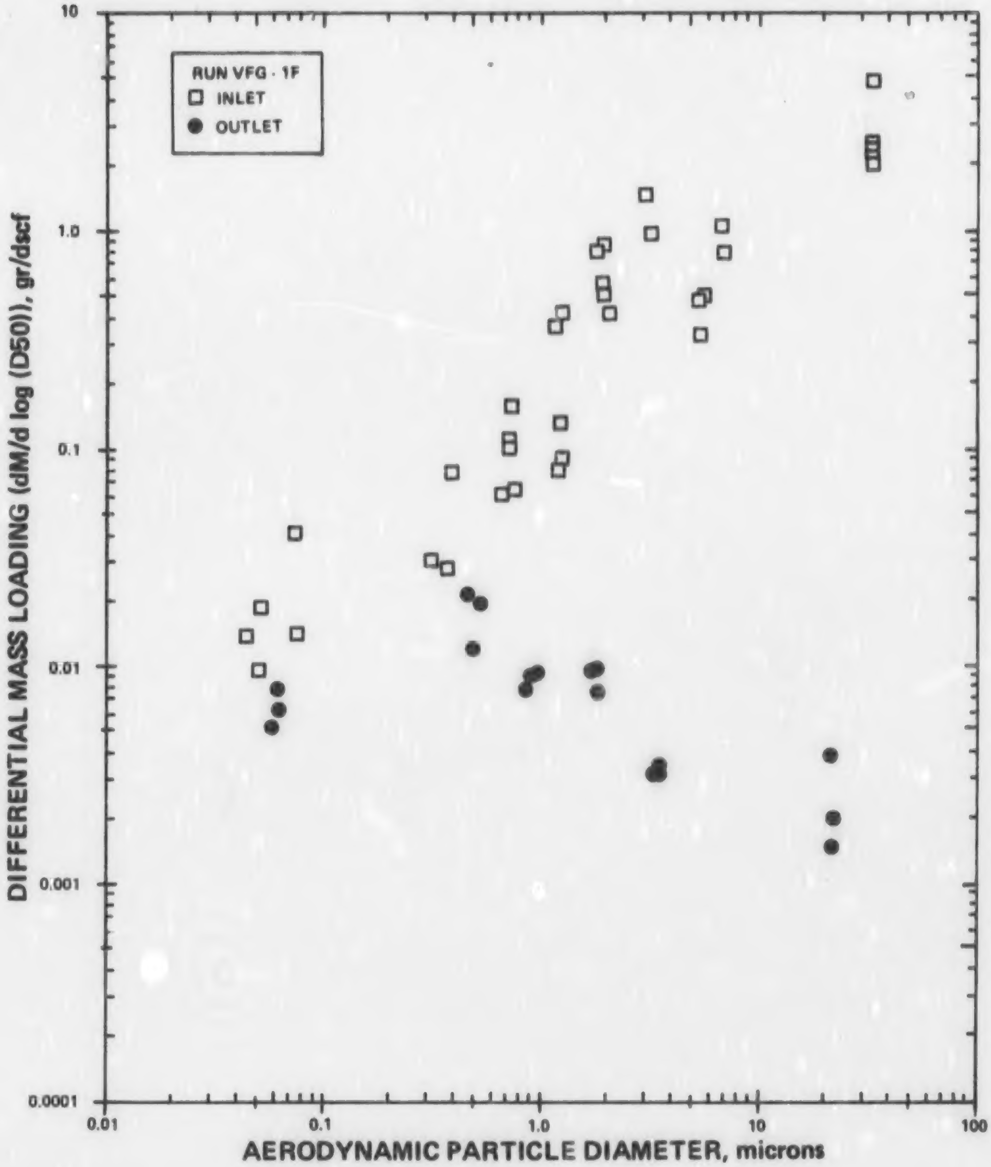

Figure 8-11. Differential Grain Loading Versus Particle Diameter for Run VFG-1F

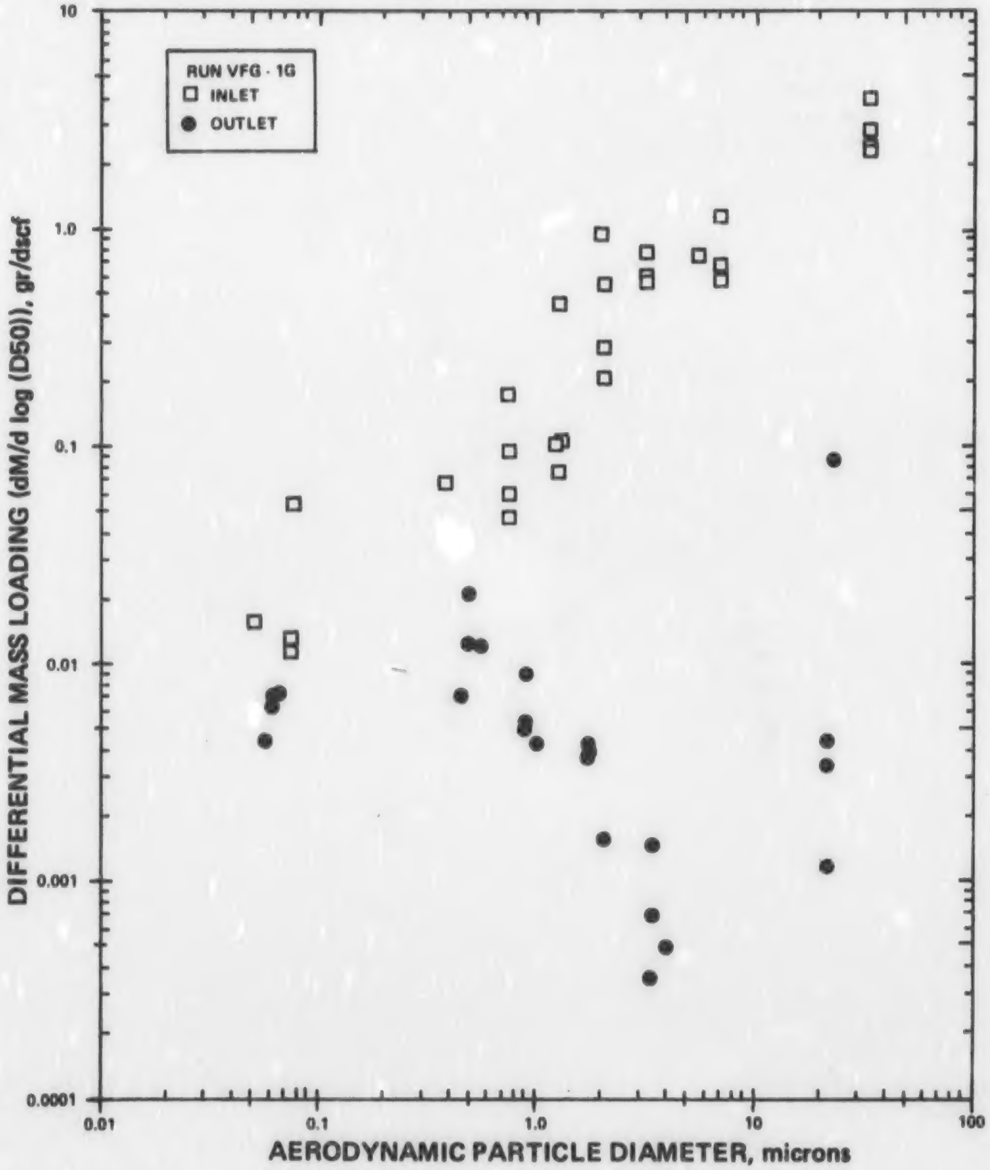

Figure 8-12. Differential Grain Loading Versus Particle Diameter for Run VFG-1G

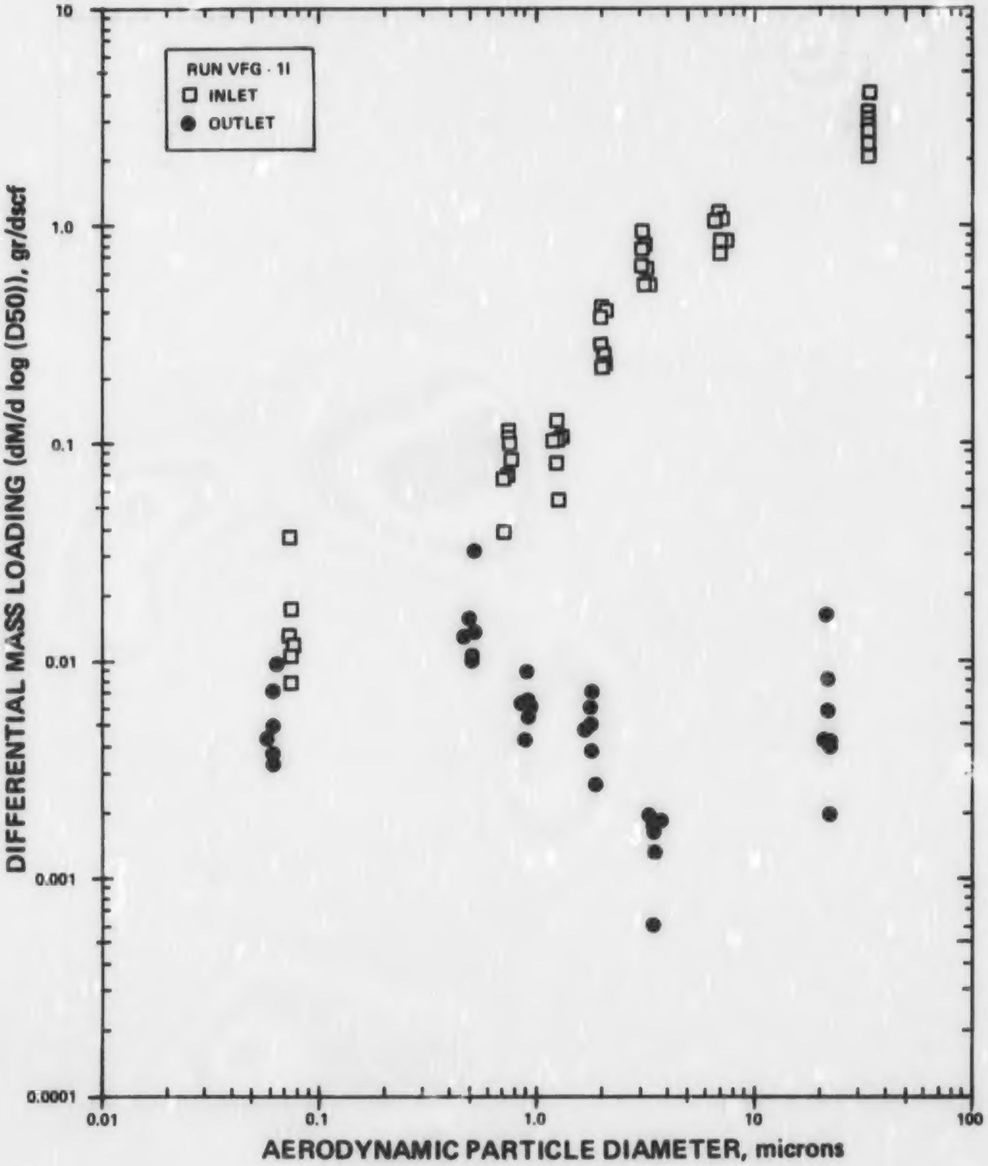

Figure 8-13. Differential Grain Loading Versus Particle Diameter for Run VFG-1I

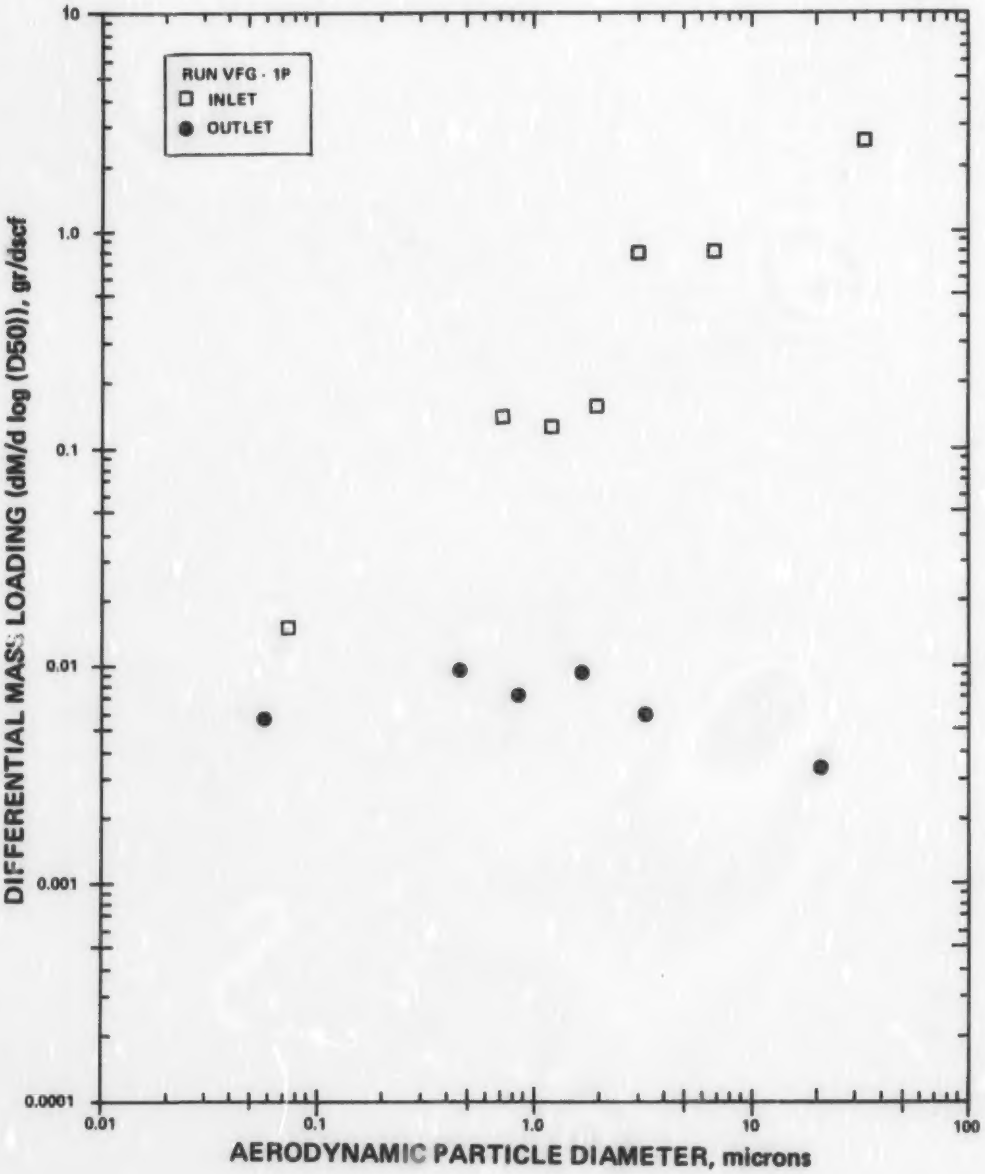

Figure 8-14. Differential Grain Loading Versus Particle Diameter for Run VFG-1P

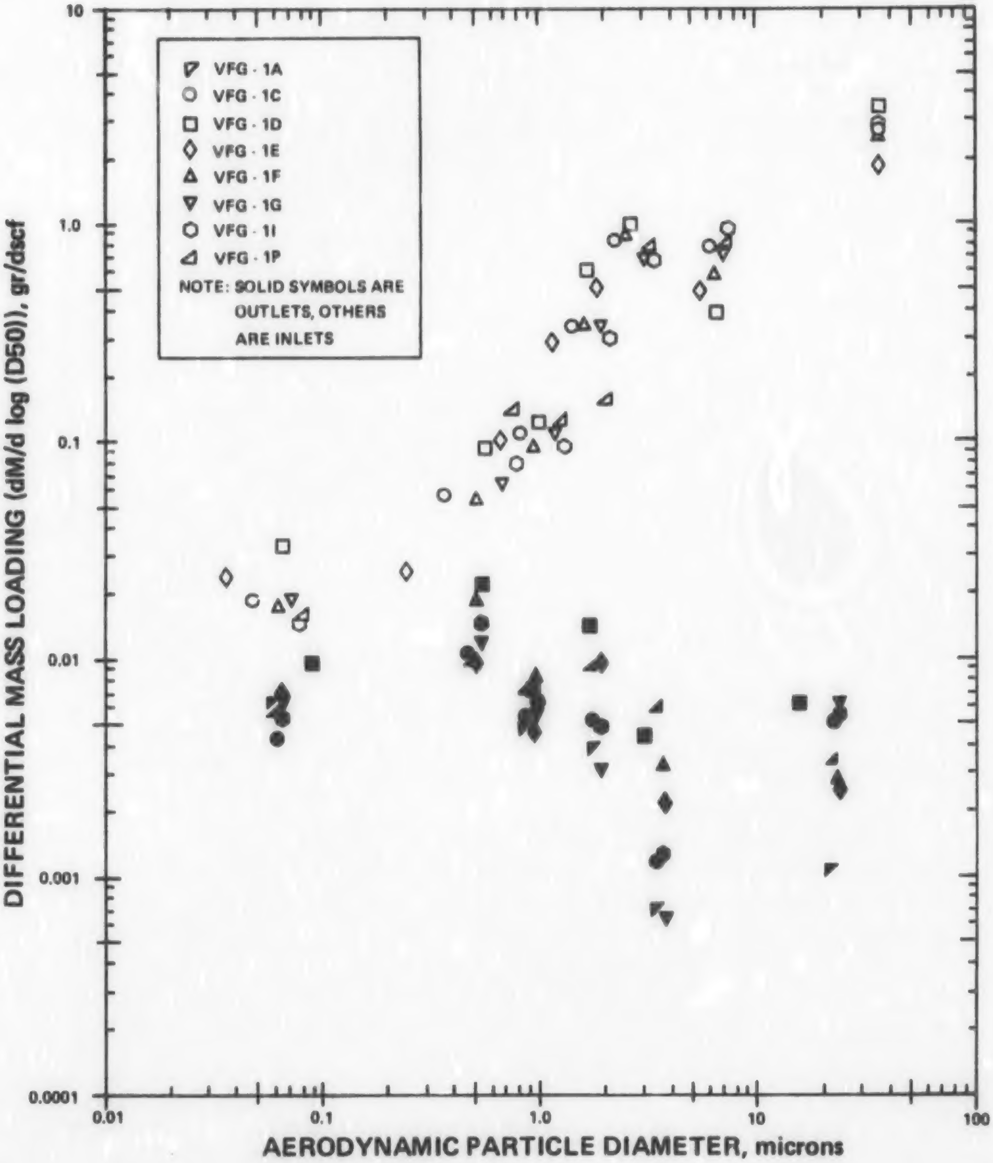

Figure 8-15. Mean Differential Grain Loading Versus Particle Size for All Runs with Fly Ash

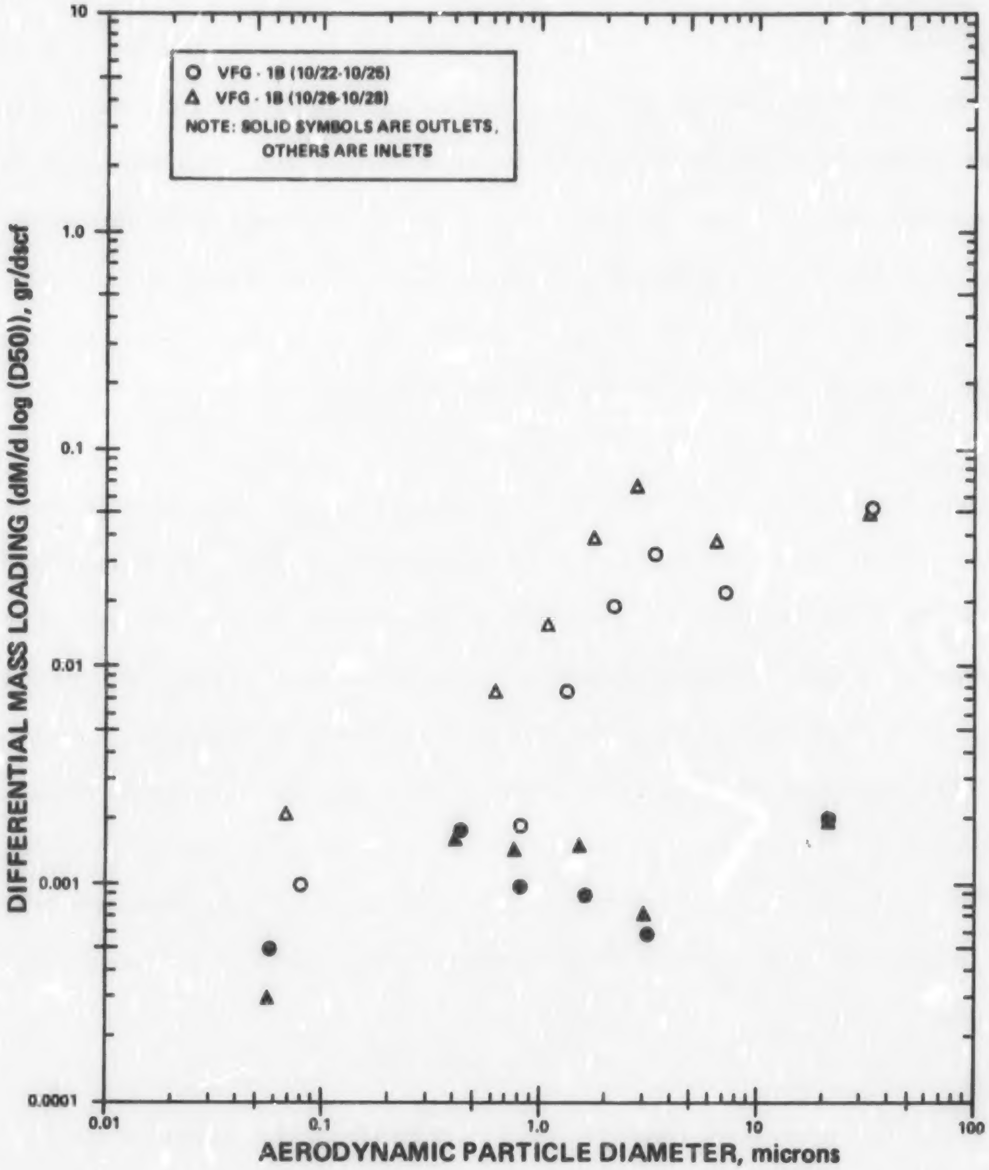

Figure 8-16. Mean Differential Grain Loading Versus Particle Size for Run VFG-1B (Low Fly-Ash Concentration Run)

Mass penetration (1 - fraction removal) as a function of particle size is plotted in Figure 8-17 for all runs with fly ash and in Figure 8-18 for the run with low fly ash. As can be seen in these figures, mass penetration appears to be fairly independent of run variable levels. The removals decrease at the smaller particle sizes, even approaching zero for the run with low fly ash (VFG-1B), but there was no indication of fine-particulate generation by the scrubber (i.e., outlets higher than inlets) over the sizes investigated.

It should be noted here that all size distribution measurements were taken out of stack to facilitate temperature control. A side effect of using this method is particulate deposition in the probe. The expected sized of these deposits were estimated using the probe residence time and the Stokes law particle settling rate as a function of size. Because of the first three stages of the impactor collect particles in the same size range as the estimated probe fallout, the probe wash and the first three stages were combined when computing grain loading as a function of particle size for the outlet size distributions.

SEM photographs (see Figures 8-19 and 8-20) of the impactor particulate captured on the third stage (5 to 6 μ cut size) and sixth stage (0.70 to 0.80 μ cut size) indicate that crystals of $CaSO_3 \cdot 1/2H_2O$ (the rosettes) are visible on the third stage and that very little of the

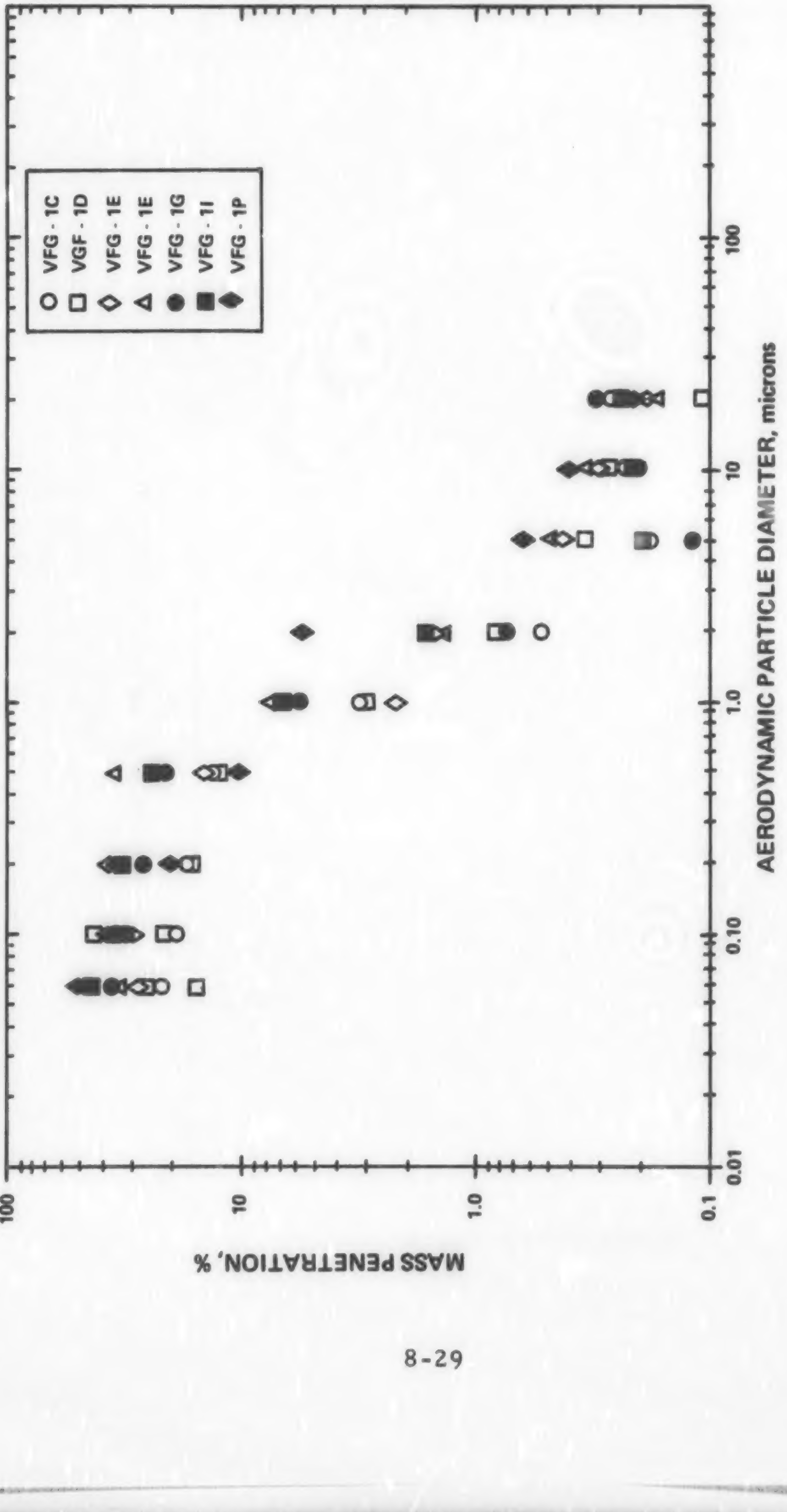

Figure 8-17. Particle Percent Penetration Versus Particle Diameter for Venturi/Spray Tower Runs with Fly Ash

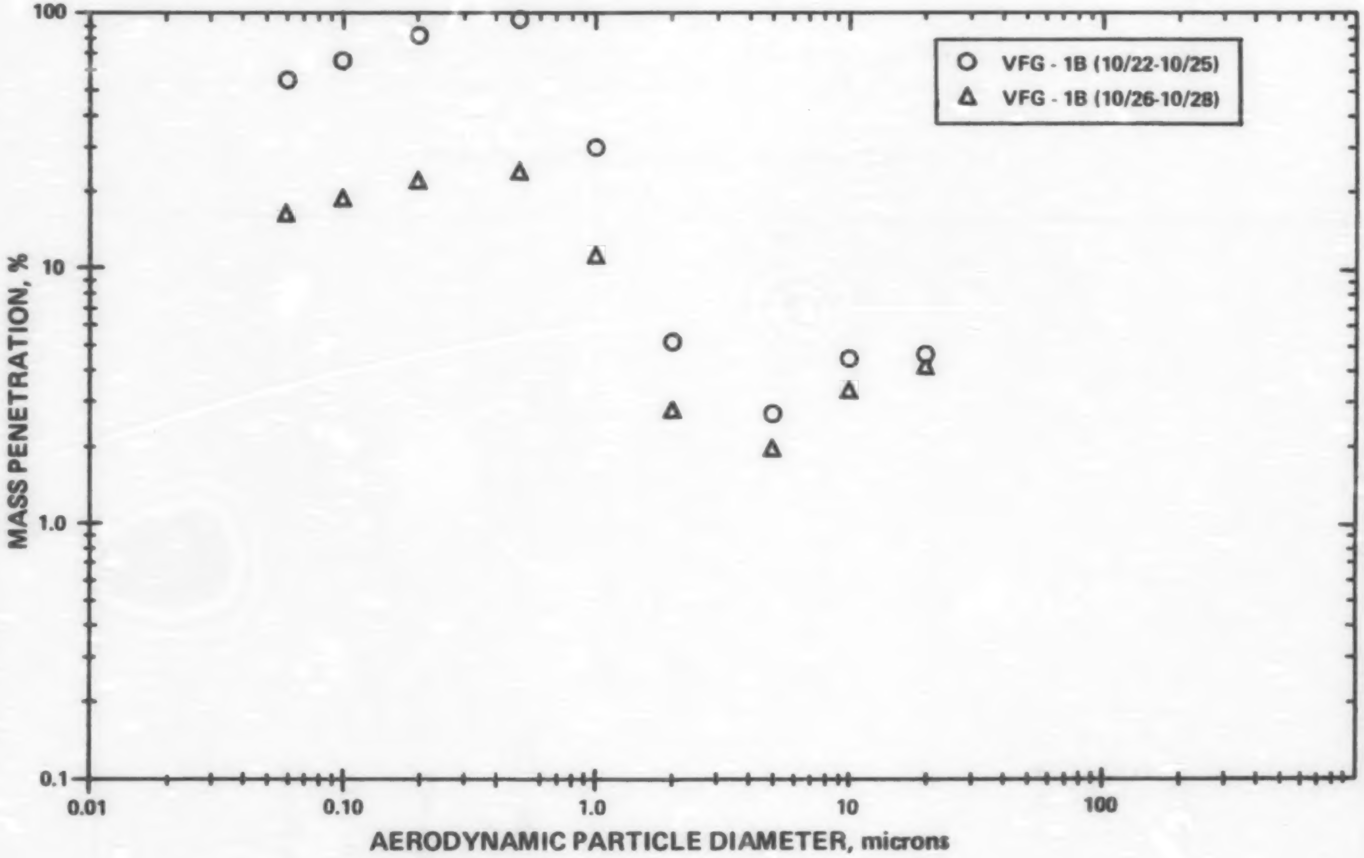

Figure 8-18. Particle Percent Penetration Versus Particle Diameter for Venturi/Spray Tower Fly Ash-Free Run VFG-1B

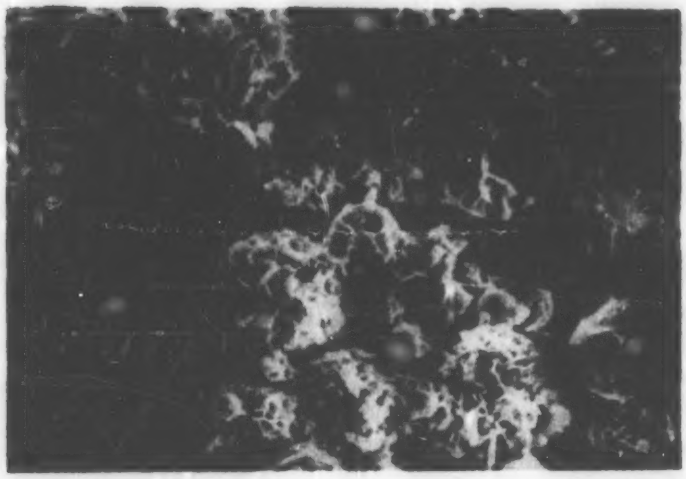

Figure 8-19. Particulate on third stage of outlet impactor during Venturi/Spray Tower run VFG-1A. Magnification 2000X.

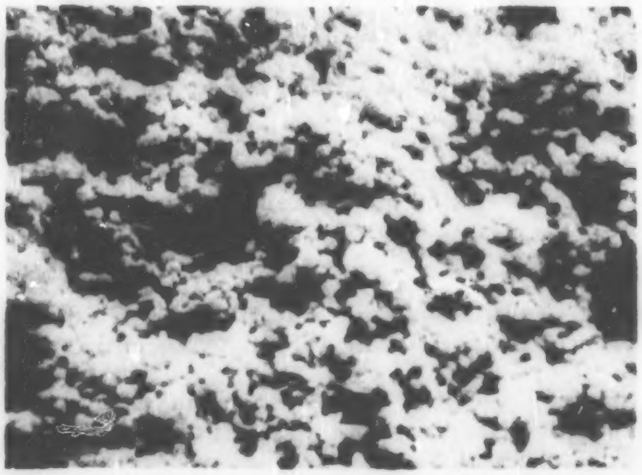

Figure 8-20. Particulate on sixth stage of outlet impactor during Venturi/Spray Tower run VFG-1A. Magnification 5000X.

emitted scrubber reaction products are visible on the sixth stage (deposits appear to be all spherical fly ash). These SEM photographs confirm the presence of scrubber reaction products while indicating their restriction to the larger sizes.

Future chemical analysis using X-ray techniques in conjunction with the SEM is expected to provide a better estimate of the amount of reaction products emitted and their size distribution.

8.4 FUTURE PLANS

Future flue gas characterization plans include the following:

- Testing on the TCA system is expected to begin in early February 1977, with gas rate, liquor rate, MgO addition, and mist eliminator wash scheme being the variables investigated
- Size distribution tests and analysis of particulate from the mass loading will be continued to obtain a more difinitive value for the amount of reaction products emitted and their size distribution
- An opacity meter will be installed to provide opacity data as a function of mass loading for Shawnee emissions
- After testing on the TCA system is completed, an attempt will be made to determine the efficiency of the mist eliminator
- To obtain a better determination of the mass distribution profile in the ducts, the gas stream will be sampled with an IKOR continuous sampler

8.5 CONCLUSIONS

These conclusions are relevant to the venturi/spray tower system only.

8.5.1 Mass Loading

The following conclusions regarding mass loading were reached:

- The outlet mass loadings were all within EPA New Source Performance Standards of 0.055 grain/dry scf at 30 percent excess air. They range typically from 0.02 to 0.04 grain/dry scf for fly ash runs and 0.003 to 0.009 grain/dry scf for the run with low fly ash
- Outlet mass loadings compared to the EPA standard were relatively unaffected by operating variable levels
- The new data were more consistent than the old data. Values were generally higher at the inlet (5 versus 3 griains/dry scf) and approximately the same for the outlet if the extreme points from the old data were neglected. The new data are believed to be more reliable
- Reaction products emission must be less than the emission value for the low fly ash run (0.003 to 0.009 grain/dry scf), and from chemical analysis was estimated to be a maximum of 50 percent of this value

8.5.2 Sulfuric Acid Vapor

The following conclusions regarding sulfuric acid vapor were reached:

- Sulfuric acid mist emission ranged from 0 to 13.8 ppm

- Sulfuric acid mist removal was fairly constant at 58 percent, with a standard error of 1.4 ppm of SO_3

- For a worst case set of scrubber outlet conditions (600 ppm SO_2, 13.8 ppm SO_3 and 0.0045 grain/dry scf scrubber reaction products), the percent sulfur emitted on a mole basis is 97.7 percent from SO_2, 2.2 percent from SO_3, and 0.1 percent from the scrubber reaction products

8.5.3 Size Distribution

The following conclusions regarding size distribution were reached:

- Grain loading and mass penetration as functions of particle size appeared to be fairly independent of operating variables levels over the levels investigated

- The scrubbing process did not contribute to fine particle emission (i.e., all outlets were less than or equal to inlets), however, some reaction products were observed in the greater than 5 μ size range

Section 9

TCA FACTORIAL TEST RESULTS

From February through April 1976 a series of 137 (6 to 8-hour) limestone, lime, and limestone/MgO factorial tests were conducted on the TCA system. The purpose of these tests was to observe the effect of different levels of the major operating variables on SO_2 removal. The test results are presented in this section. Corrections of the data are presented in Section 14.

The measures taken to ensure data quality for these TCA factorial tests and the problems encountered were the same as for the venturi/spray tower factorial tests (see Subsection 6.1). The coal used during the limestone/MgO testing had an unexpectedly high chloride content; the scrubber liquor chloride concentration ranged from 10,000 to 20,000 ppm, compared to 2000 to 6000 ppm for "normal" Shawnee coal. As in the venturi/spray tower factorial tests, this high chloride may account for the disagreement between the factorial data and earlier long term data. The correlation of chloride ion concentration wtih SO_2 removal is discussed in Section 14.

9.1 LIMESTONE TESTING

Table 9-1 gives the data from the 49 limestone factorial tests on the TCA. Independent variables tested with the TCA limestone system were:

- Gas flow rate
- Slurry recirculation rate
- Scrubber inlet liquor pH
- Sphere bed height

Figure 9-1 illustrates the effect of scrubber inlet pH on SO_2 removal at different liquid-to-gas ratios. For the data given in this figure, superficial gas velocity* was 10.4 ft/sec, and the TCA operated with three 5-inch-deep beds of 6.5-gram nitrile foam spheres, nominally 1-1/2 inches in diameter. The data show that SO_2 removal increases with both increasing pH and increasing liquid-to-gas ratio.

Figure 9-2 shows the effects on SO_2 removal of changing slurry flow rate and gas velocity independently in the TCA with three 5-inch beds. SO_2 removal is a strong positive function of slurry flow rate and a slight positive function of gas velocity (decreasing L/G). At

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* Gas velocity is calculated at scrubber temperature (nominally 125°F). The TCA cross-sectional area is 32 ft^2 in the scrubber section.

Table 9-1

SUMMARY OF LIMESTONE FACTORIAL TESTS ON THE TCA

Run Number	Gas Rate, acfm	Liquor Rate, gpm	Gas Vel., ft/sec	L/G, gal/Mcf	Total Sphere Height, in.	Bed Press. Drop, in. H_2O	Scrubber Inlet Liquor pH		Scrubber Outlet Liquor pH	Inlet SO_2 Conc., ppm		Percent SO_2 Removal		Replicate Number
							Range	Avg.		Range	Avg.	Range	Avg.	
TCA101	30000	900	12.5	37	15.0	7.2	5.76-5.80	5.78		2520-2800	2686	79-82	80	
TCA102	20000	600	8.4	37	15.0	3.6	5.88-5.95	5.92	5.53	2400-2640	2533	70-72	71	F
TCA103	25000	1200	10.4	60	15.0	6.0	5.81-5.95	5.88		2600-2760	2669	86-88	87	
TCA104	25000	900	10.4	45	15.0	4.9	5.71-5.84	5.76	5.49	2080-2560	2360	75-80	77	E
TCA105	30000	1200	12.5	50	15.0	9.7	5.78-5.86	5.81		2320-2560	2412	91-94	92	A
TCA106	20000	1200	8.4	75	15.0	4.9	5.74-5.85	5.80	5.20	2560-2600	2589	82-85	84	
TCA107	20000	900	8.4	56	15.0	4.2	5.74-5.79	5.77	5.39	2480-2560	2520	72-77	74	
TCA108	25000	600	10.4	30	15.0	4.3	5.80-5.92	5.86		2400-2520	2466	67-70	68	
TCA109	30000	600	12.5	25	15.0	5.5	5.78-5.88	5.83	5.24	2400-2520	2434	69-71	70	
TCA110	30000	1200	12.5	50	15.0	9.2	5.69-5.85	5.77	5.30	2400-2560	2507	89-91	90	A
TCA111	25000	600	10.4	30	22.5	6.2	5.40-5.56	5.46		2480-2720	2631	63-67	65	
TCA112	25000	1200	10.4	60	22.5	9.1	5.43-5.48	5.46		2640-2700	2684	84-88	85	B
TCA113	25000	900	10.4	45	22.5	7.1	5.69-5.82	5.76		2800-2840	2810	81-85	82	
TCA114	25000	1200	10.4	60	22.5	9.0	5.60-5.69	5.65	5.32	2800-2840	2820	91-94	92	B
TCA115	30000	900	12.5	37	0.0	1.8	5.81-5.99	5.90		2640-2800	2680	65-67	66	L
TCA116	20000	600	8.4	37	0.0	0.4	6.04-6.24	6.11	5.82	2640-2760	2700	60-61	61	J
TCA117	25000	1200	10.4	60	0.0	1.6	6.02-6.17	6.08	5.77	2720-2760	2750	77-79	78	I
TCA118	25000	900	10.4	45	0.0	1.2	6.00-6.02	6.01	5.89	2800-2960	2920	63-65	64	K
TCA119	30000	1200	12.5	50	0.0	2.2	5.74-5.94	5.85	5.43	2840-3000	2909	69-71	70	C
TCA120	20000	1200	8.4	75	0.0	0.9	5.79-5.93	5.84	5.34	2920-2920	2920	70-72	71	
TCA121	20000	900	8.4	56	0.0	0.7	5.84-5.97	5.89		2720-2740	2725	62-66	63	
TCA122	25000	600	10.4	30	0.0	0.7	5.80-5.90	5.86		2700-2760	2743	45-47	46	
TCA123	30000	600	12.5	25	0.0	1.3	5.67-5.86	5.75		2600-3000	2755	46-48	47	
TCA124	30000	1200	12.5	50	0.0	2.2	5.75-5.86	5.82		2680-2840	2743	66-70	68	C
TCA125	25000	1200	10.4	60	15.0	5.6	5.48-5.66	5.55		2280-2640	2427	74-81	78	
TCA126	25000	600	10.4	30	15.0	4.2	5.41-5.59	5.52	5.12	2600-2800	2672	58-62	61	
TCA127	25000	900	10.4	45	15.0	4.8	5.43-5.67	5.52		2560-2680	2623	72-78	74	G
TCA128	25000	1200	10.4	60	15.0	5.7	5.13-5.40	5.28	5.02	2600-2940	2749	63-80	71	D
TCA129	25000	600	10.4	30	15.0	4.1	5.11-5.22	5.18	4.97	2440-2560	2520	47-51	49	
TCA130	25000	900	10.4	45	15.0	5.3	5.20-5.42	5.33		2400-2480	2440	63-70	67	H
TCA131	25000	1200	10.4	60	15.0	5.9	4.95-5.06	5.01		2480-2520	2513	63-68	66	D
TCA132	25000	1200	10.4	60	22.5	8.8	5.19-5.29	5.24	4.94	2640-2800	2720	68-72	70	
TCA133	25000	1200	10.4	60	0.0	1.6	5.11-5.30	5.19		2400-2480	2440	49-53	51	M
TCA134	25000	900	10.4	45	15.0	4.9	5.78-5.87	5.82	5.30	2640-2720	2688	78-80	79	E
TCA135	30000	1200	12.5	50	15.0	9.7	5.90-5.93	5.92	5.65	2560-2640	2593	95-96	95	A
TCA136	20000	600	8.4	37	15.0	3.5	5.71-5.87	5.79	5.25	2500-2600	2544	67-70	68	F
TCA137	25000	900	10.4	45	15.0	5.3	5.41-5.87	5.75	5.32	2440-2720	2543	77-82	79	E
TCA138	25000	900	10.4	45	15.0	5.3	4.98-5.08	5.04	5.14	2680-2800	2747	58-62	60	G
TCA139	25000	900	10.4	45	15.0	5.7	4.78-5.11	4.93		2600-2880	2785	52-60	57	H
TCA140	25000	1200	10.4	60	0.0	2.1	5.83-5.86	5.84		2480-2680	2606	67-68	67	I
TCA141	20000	600	8.4	37	0.0	0.8	5.71-5.89	5.84	5.21	2520-2600	2554	50-54	52	J
TCA142	25000	900	10.4	45	0.0	1.7	5.79-5.82	5.80	5.18	2520-2640	2566	56-59	57	K
TCA143	30000	900	12.5	37	0.0	2.4	5.74-5.81	5.78	5.08	2640-2760	2685	58-63	59	L
TCA144	20000	600	8.4	37	15.0	4.5	5.79-5.91	5.85	4.96	2400-2600	2473	68-72	70	F
TCA145	25000	1200	10.4	60	15.0	6.7	5.19-5.36	5.28	4.91	2160-2440	2360	69-74	72	D
TCA146	25000	1200	10.4	60	0.0	2.2	5.47-5.57	5.51		2400-2400	2450	56-59	57	
TCA147	25000	1200	10.4	60	0.0	2.0	5.16-5.28	5.24		2560-2600	2583	46-52	50	M
TCA148	25000	900	10.4	45	0.0	1.7	5.22-5.28	5.24		2520-2760	2647	43-47	45	
TCA149	25000	900	10.4	45	0.0	1.6	5.39-5.57	5.51	4.86	2720-2800	2765	49-53	52	

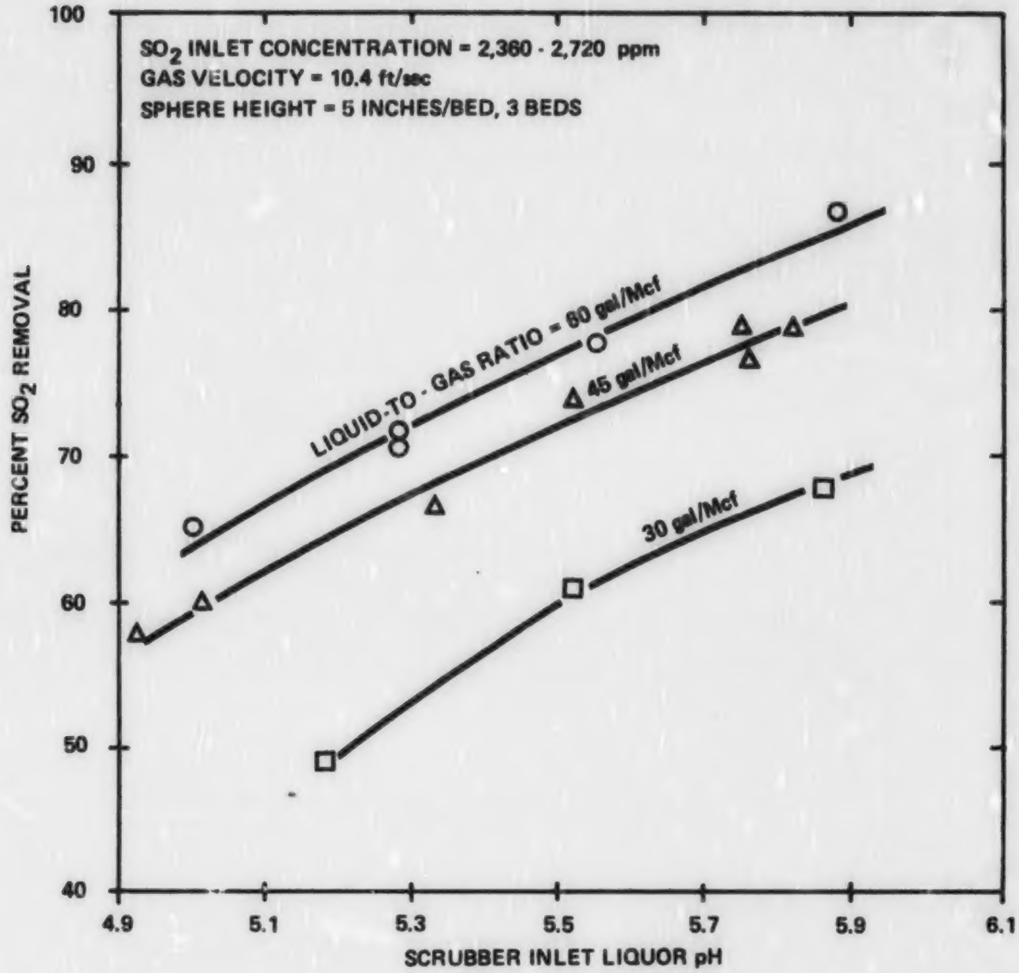

Figure 9-1. Effect of Scrubber Inlet Liquor pH and Liquid-to-Gas Ratio on SO$_2$ Removal - TCA with Limestone

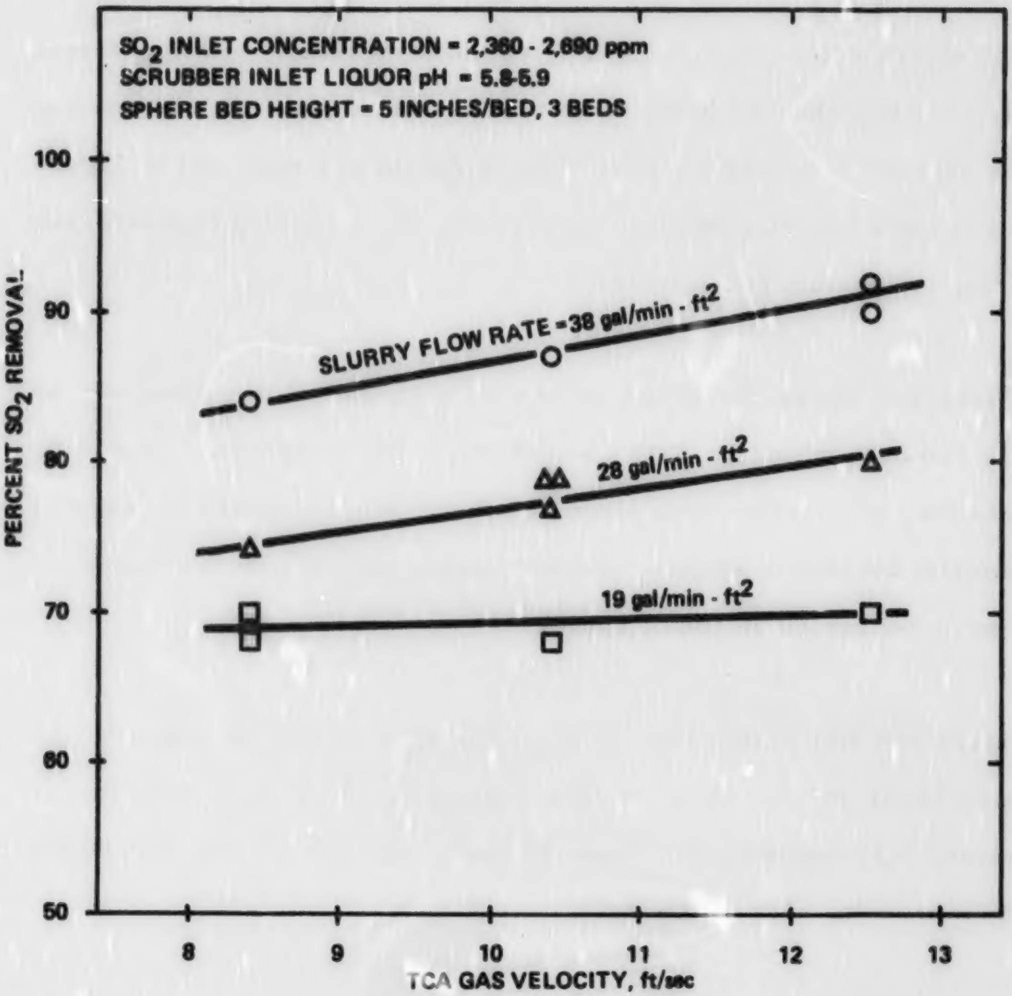

Figure 9-2. Effect of Gas Velocity and Slurry Flow Rate on SO_2 Removal - TCA with Limestone

high slurry rates (38 gal/min-ft^2), removal increases with increasing gas velocity, whereas in the spray tower it decreases with increasing gas velocity (see Figure 6-7). The TCA data are replotted in Figure 9-3 to show how SO_2 removal increases with increasing liquid-to-gas ratio, at constant gas velocity.

Figure 9-4 shows the effect of gas velocity and slurry flow rate on SO_2 removal when the TCA is operating with no spheres. It can be seen that slurry flow rate strongly affects SO_2 removal and that SO_2 removal decreases slightly with increasing gas velocity (compare Figure 9-2 for 15 inches of spheres).

Figure 9-5 illustrates the effect of the total height of spheres (for three beds) in the TCA on SO_2 removal at different liquid-to-gas ratios. SO_2 removal increases strongly with increasing bed height and increasing slurry flow rate.

9.2 LIME TESTING

Table 9-2 presents the data from the 37 lime factorial tests on the TCA. Independent variables tested with the TCA lime system were:

- Gas flow rate
- Slurry recirculation rate

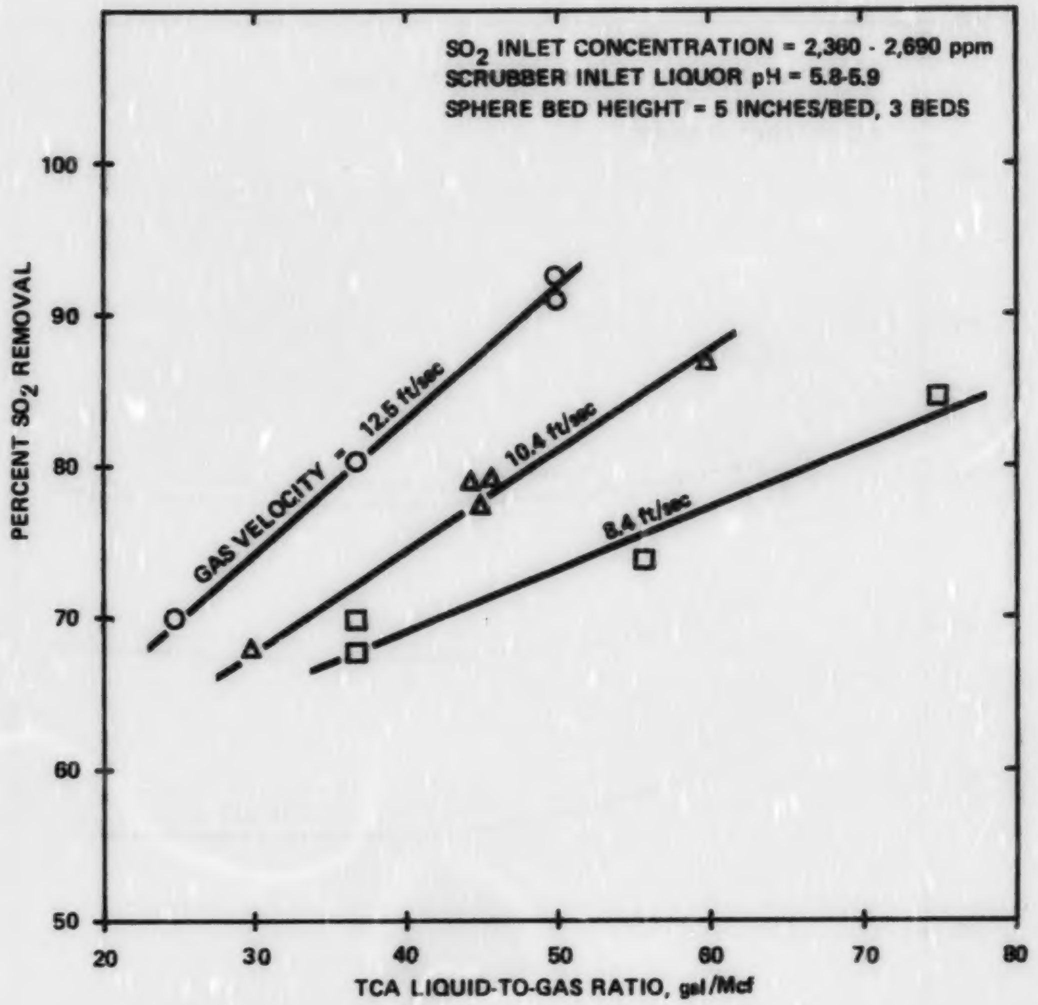

Figure 9-3. Effect of Liquid-to-Gas Ratio and Gas Velocity on SO_2 Removal - TCA with Limestone

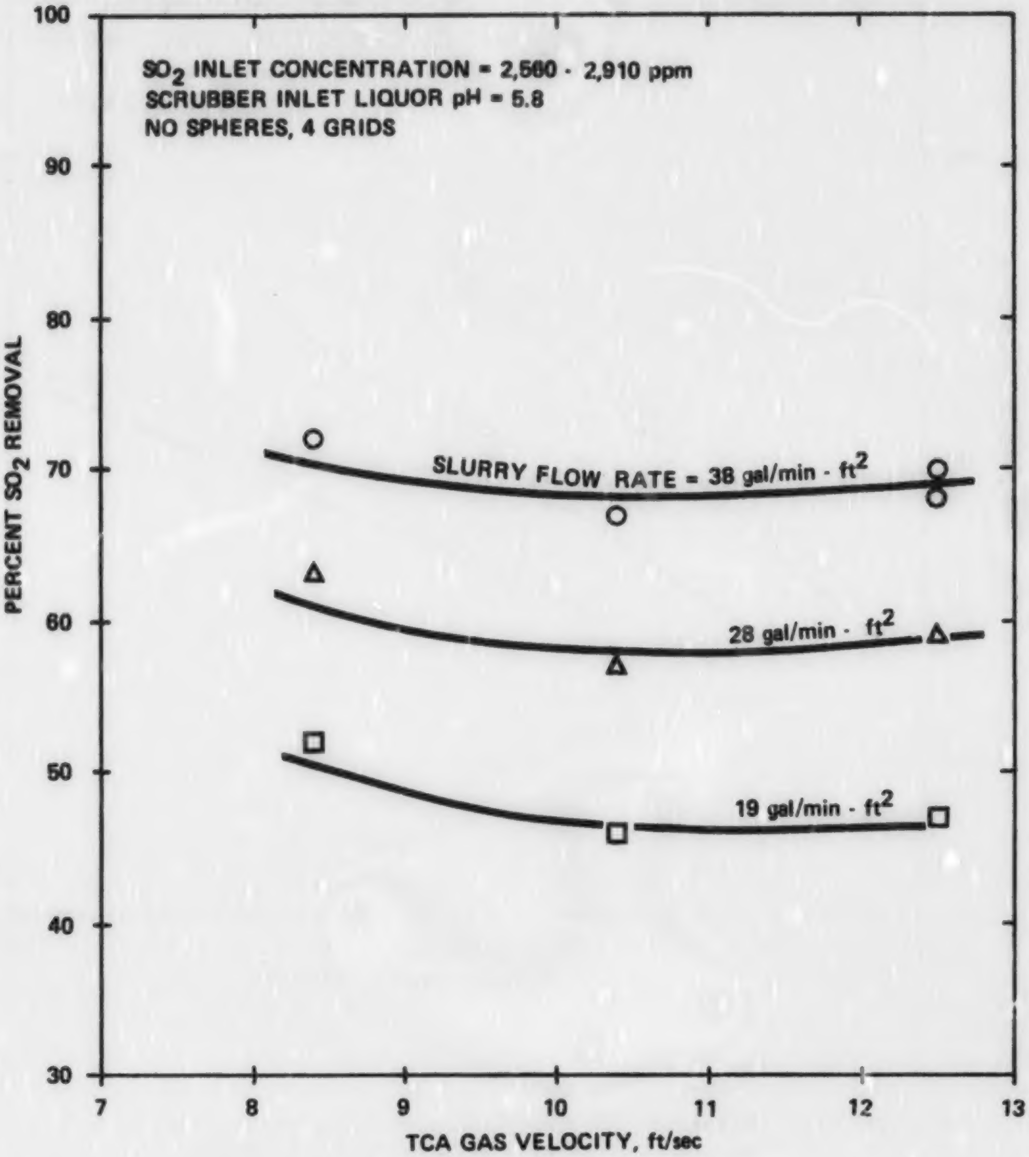

Figure 9-4. Effect of Gas Velocity and Slurry Flow Rate on SO$_2$ Removal - TCA (No Spheres) with Limestone

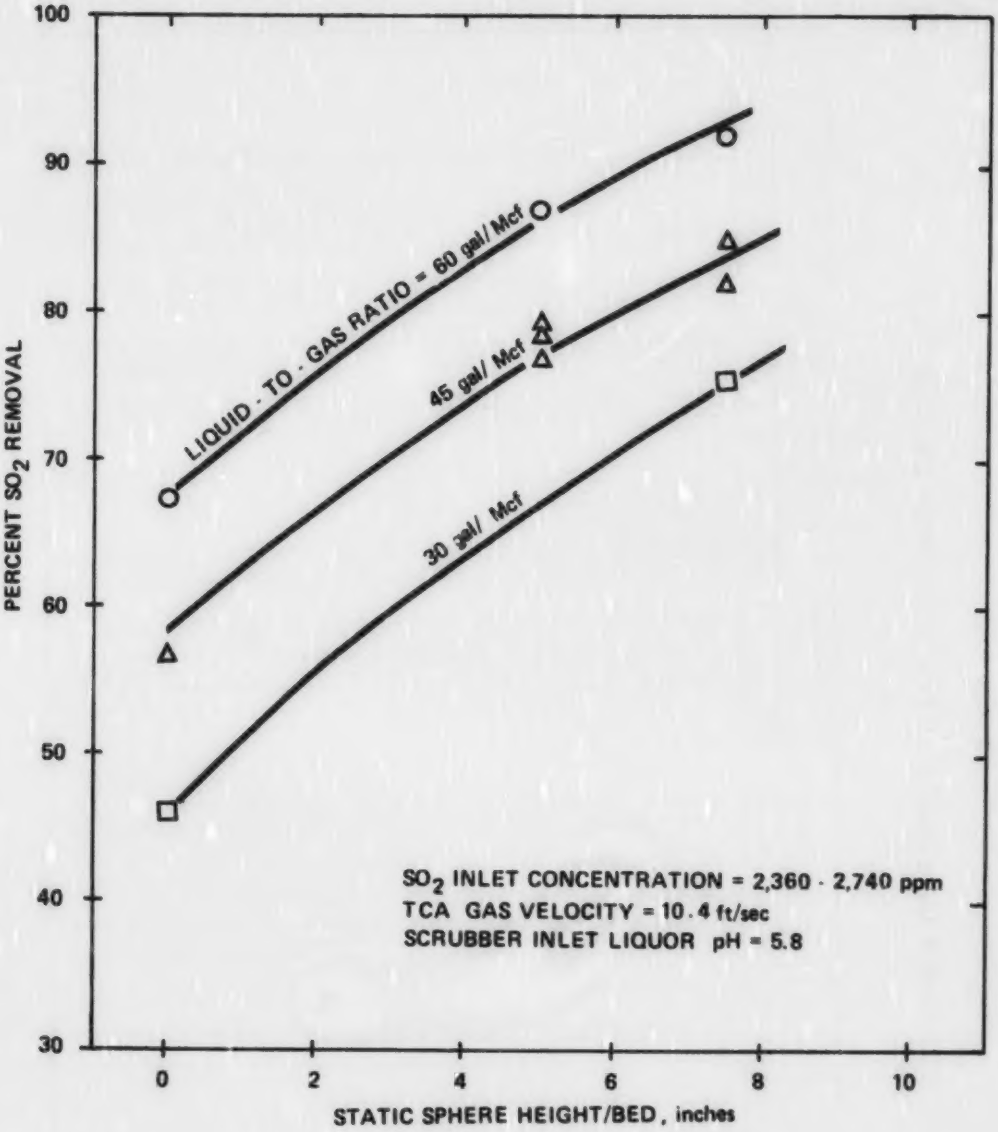

Figure 9-5. Effect of Sphere Bed Height and Liquid-to-Gas Ratio on SO_2 Removal - Three-Bed TCA with Limestone

Table 9-2

SUMMARY OF LIME FACTORIAL TESTS ON THE TCA

Run Number	Gas Rate, acfm	Liquor Rate, gpm	Gas Vel., ft/sec	L/G, gal/Mcf	Total Sphere Height, in.	Bed Press. Drop, in. H_2O	Scrubber Inlet Liquor pH		Scrubber Outlet Liquor pH	Inlet SO_2 Conc., ppm		Percent SO_2 Removal		Replicate Number
							Range	Avg.		Range	Avg.	Range	Avg.	
TCA001	30000	900	12.5	37	15.0	7.6	7.97-8.10	8.04		2440-2560	2497	73-77	74	
TCA002	20000	600	8.4	37	15.0	6.7	7.95-8.40	8.10	4.88	2400-2600	2500	57-61	60	
TCA003	25000	1200	10.4	60	15.0	6.2	7.80-8.32	8.02		2360-2480	2431	86-87	86	F
TCA004	25000	900	10.4	45	15.0	5.5	7.97-8.27	8.13	4.96	2340-2440	2400	72-75	73	
TCA005	30000	1200	12.5	50	15.0	11.9	8.09-8.26	8.14	4.73	2480-2560	2512	91-92	92	A
TCA006	20000	1200	8.4	75	15.0	5.3	7.98-8.43	8.22		2400-2480	2440	85-89	87	
TCA007	20000	900	8.4	56	15.0	4.1	7.82-8.08	7.95	4.84	2160-2360	2257	72-77	73	
TCA008	25000	600	10.4	30	15.0	3.8	8.07-8.18	8.12	4.72	2460-2500	2480	54-59	57	E
TCA009	30000	600	12.5	25	15.0	5.6	7.93-8.20	8.03	4.52	2680-2800	2771	52-59	54	
TCA010	30000	1200	12.5	50	15.0	11.0	7.94-8.11	8.02	4.47	2400-2600	2512	90-91	90	A
TCA011	25000	600	10.4	30	22.5	5.8	7.80-8.06	7.91	4.57	2480-2560	2550	58-60	59	
TCA012	25000	1200	10.4	60	22.5	8.8	7.67-8.14	7.93	4.99	2480-2560	2505	88-89	89	B
TCA013	25000	900	10.4	45	22.5	7.2	8.04-8.22	8.12		2480-2560	2520	73-77	74	
TCA014	25000	1200	10.4	60	22.5	8.7	8.05-8.26	8.13		2360-2480	2420	89-91	90	B
TCA015	30000	900	12.5	37	0.0		8.05-8.35	8.20		2480-2600	2543	53-57	54	
TCA016	20000	600	8.4	37	0.0		7.89-8.16	8.06		2480-2560	2532	48-50	49	
TCA017	25000	1200	10.4	60	0.0		7.89-8.17	7.98		2400-2480	2417	68-72	70	
TCA018	25000	900	10.4	45	0.0	1.7	7.79-8.23	8.00	4.68	2400-2520	2451	58-61	59	
TCA019	30000	1200	12.5	50	0.0	3.0	8.01-8.28	8.15	4.27	2320-2460	2420	69-73	71	C
TCA020	20000	1200	8.4	75	0.0	1.7	7.77-8.12	7.99		2200-2520	2400	72-80	76	
TCA021	20000	900	8.4	56	0.0	1.2	7.68-8.30	8.01		2480-2520	2503	65-67	66	
TCA022	25000	600	10.4	30	0.0	1.3	7.95-8.26	8.08	4.64	2540-2560	2552	45-47	46	
TCA023	30000	600	12.5	25	0.0	1.8	7.89-8.07	7.97		2440-2520	2474	41-45	43	
TCA024	30000	1200	12.5	50	0.0	3.0	7.80-8.13	7.99		2320-2440	2383	61-69	67	C
TCA025	25000	600	10.4	30	15.0	4.3	6.67-7.24	6.91		2740-2800	2787	52-54	53	
TCA026	25000	1200	10.4	60	15.0	6.2	8.91-9.20	9.07	6.30	2480-2760	2571	94-96	95	
TCA027	25000	600	10.4	30	15.0	4.5	5.93-6.05	5.99		2680-2720	2707	49-49	49	
TCA028	25000	600	10.4	30	15.0	4.6	7.95-8.20	8.06		2400-2560	2477	59-61	60	E
TCA029	25000	1200	10.4	60	15.0	6.2	5.97-6.34	6.11		2360-2440	2423	73-77	74	D
TCA030	25000	600	10.4	30	15.0	4.5	8.04-9.15	9.01	4.87	2600-2680	2640	69-72	71	
TCA031	25000	1200	10.4	60	15.0	6.0	6.43-7.36	6.89		2560-2640	2605	77-81	79	
TCA032	25000	1200	10.4	60	15.0	6.1	5.95-6.25	6.06	4.62	2600-2680	2632	73-77	74	D
TCA033	25000	600	10.4	30	15.0	4.5	7.82-8.09	7.98	4.52	2600-2680	2640	57-61	58	E
TCA034	25000	1200	10.4	60	22.5	8.6	5.85-6.28	6.03		2520-2560	2540	77-79	78	
TCA035	25000	1200	10.4	60	15.0	6.5	7.94-8.23	8.09		2200-2440	2345	84-88	85	F
TCA036	25000	1200	10.4	60	15.0	6.2	5.82-6.10	5.97	4.86	2320-2380	2357	72-77	74	D
TCA037	25000	1200	10.4	60	15.0	6.2	5.98-6.22	6.00	4.50	2580-2640	2604	73-75	74	D

- Scrubber inlet liquor pH
- Sphere bed height

Figure 9-6 shows the effect of scrubber inlet liquor pH on SO_2 removal at different liquid-to-gas ratios for a superficial gas velocity of 10.4 ft/sec and three 5-inch beds of spheres. At these conditions, SO_2 removal increases as pH increases and as liquid-to-gas ratio increases.

Figure 9-7 indicates that SO_2 removal changes only slightly, if at all, with a change in gas velocity even though liquid-to-gas ratio changes. Slurry flow rate has a strong positive effect on SO_2 removal. The data are replotted in Figure 9-8 to show how SO_2 removal increases with increasing liquid-to-gas ratio at constant gas velocity.

Figure 9-9 shows the effects of independent changes in gas velocity and slurry flow rate with no spheres in the TCA (compare with Figure 9-7 with 15 inches of spheres). SO_2 removal slightly decreases with increasing gas velocity and strongly increases with increasing slurry flow rate.

Figure 9-10 shows the change in SO_2 removal with change of sphere bed height and liquid-to-gas ratio. As expected, SO_2 removal increases as bed height and liquid-to-gas ratio increase at constant gas velocity.

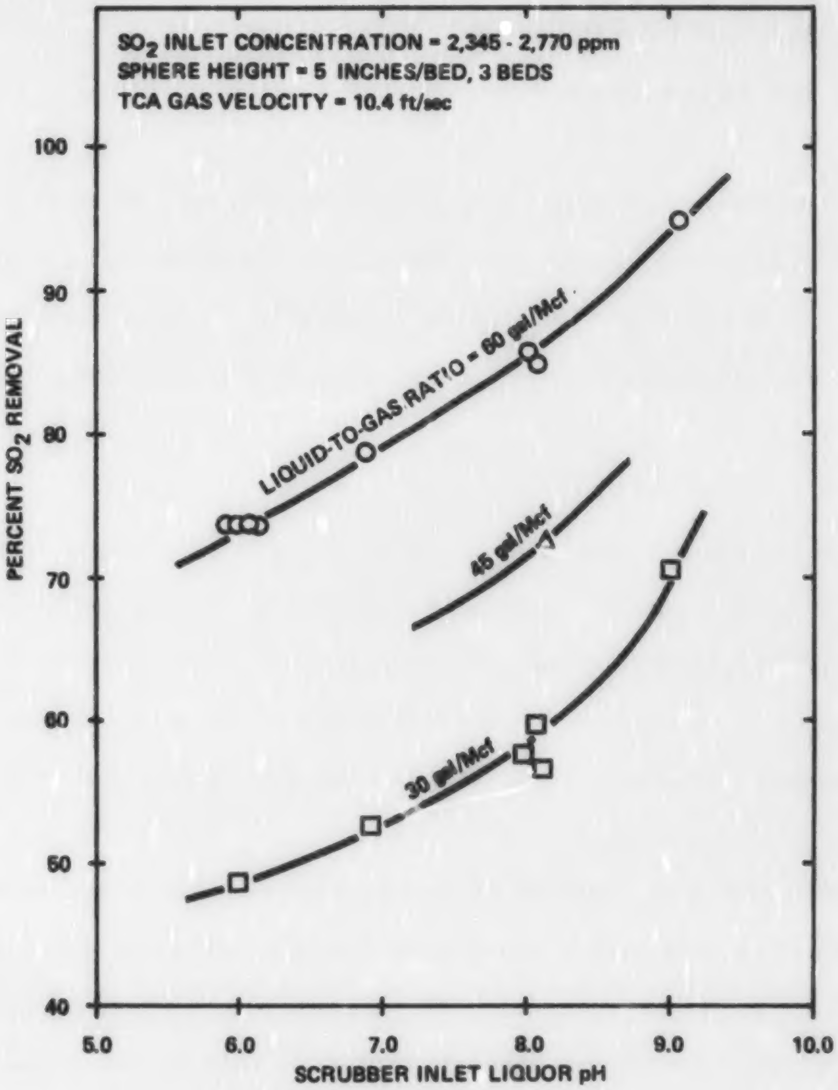

Figure 9-6. Effect of Scrubber Inlet Liquor pH and Liquid-to-Gas Ratio on SO_2 Removal - TCA with Lime

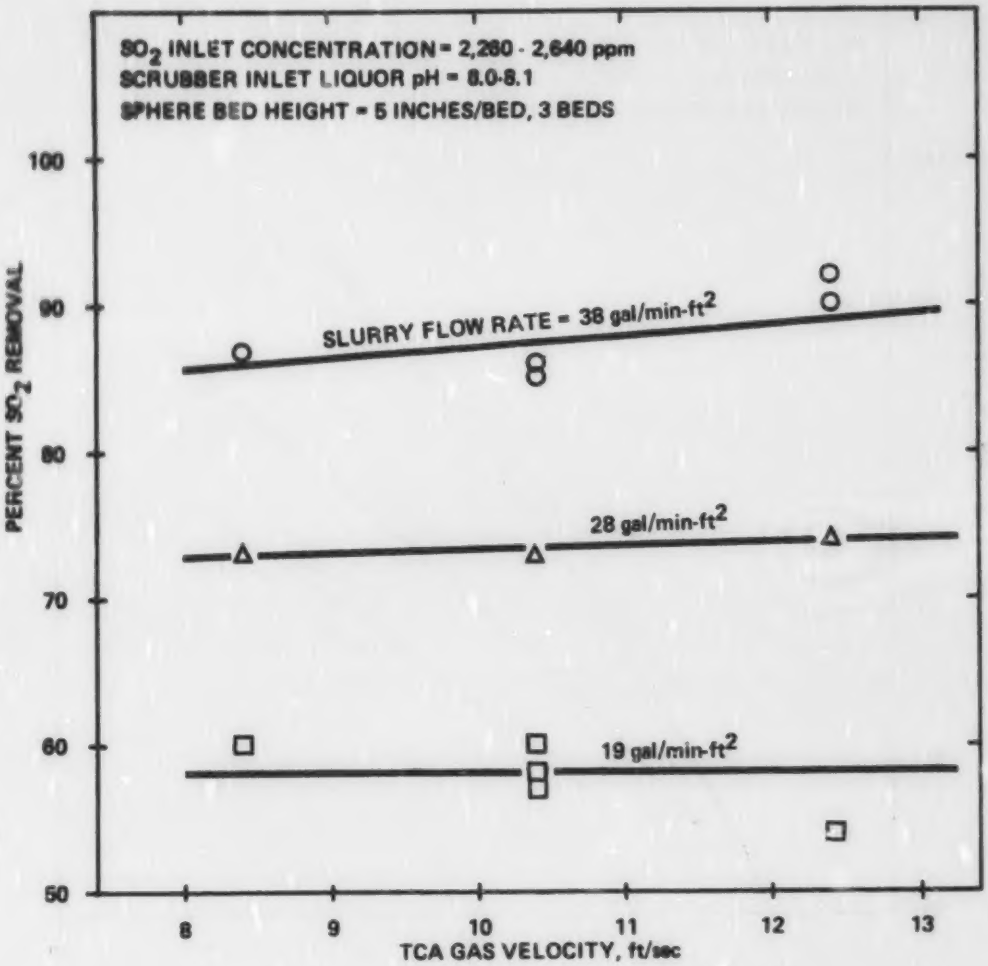

Figure 9-7. Effect of Gas Velocity and Slurry Flow Rate on SO_2 Removal - TCA with Lime

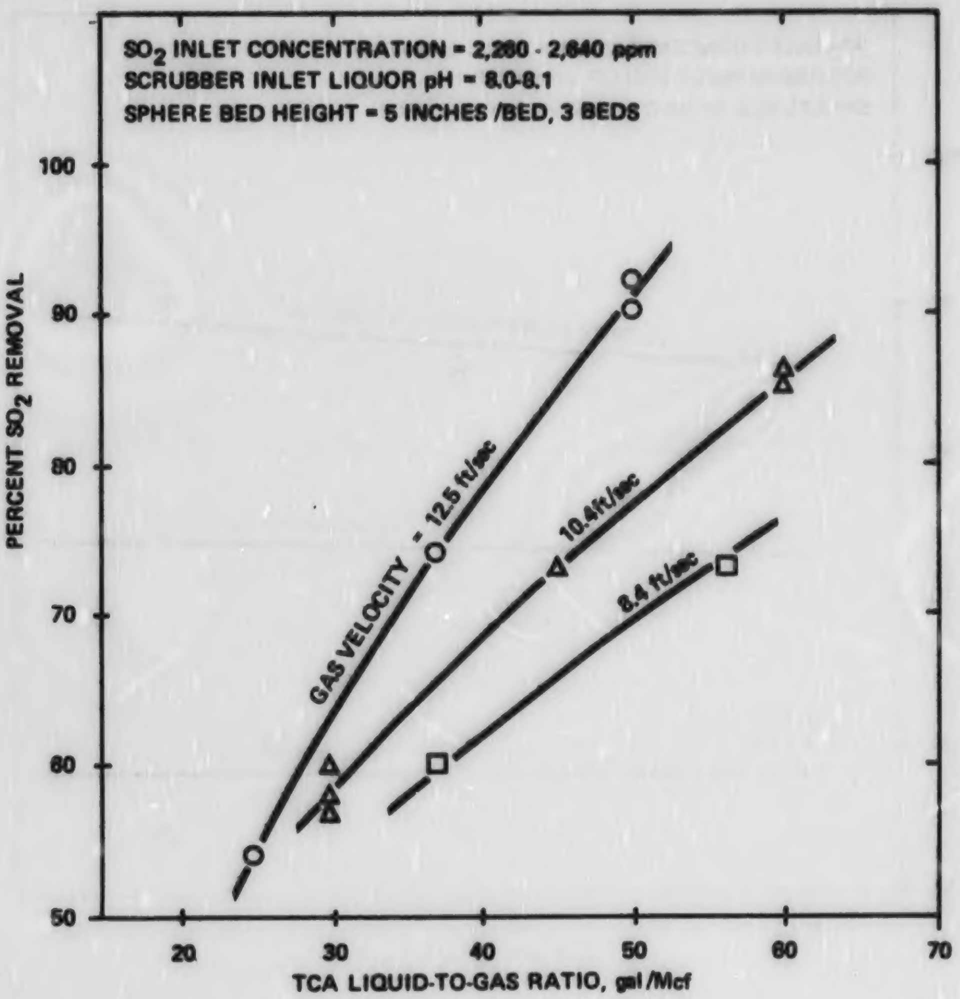

Figure 9-8. Effect of Liquid-to-Gas Ratio and Gas Velocity on SO_2 Removal - TCA with Lime

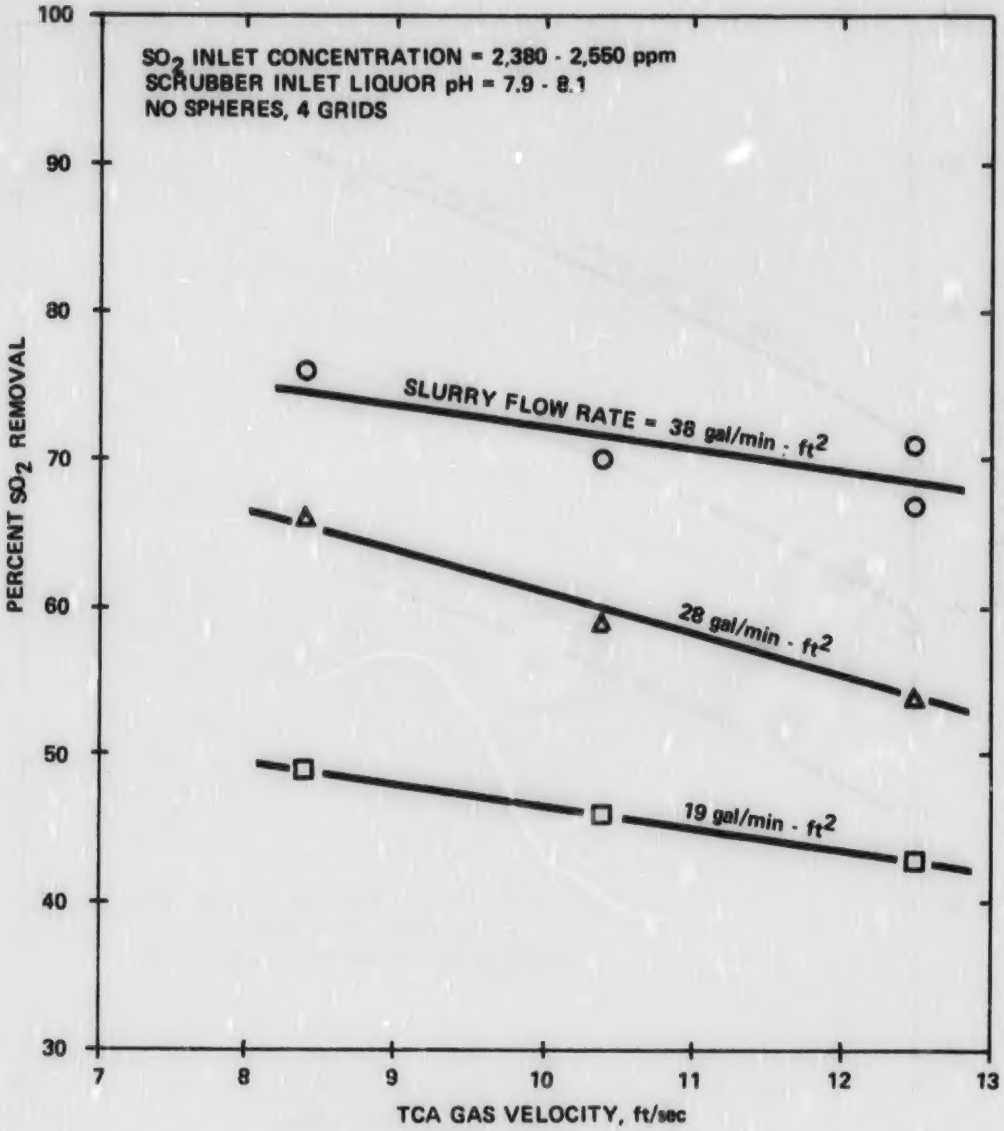

Figure 9-9. Effect of Gas Velocity and Slurry Flow Rate on SO_2 Removal - TCA (No Spheres) with Lime

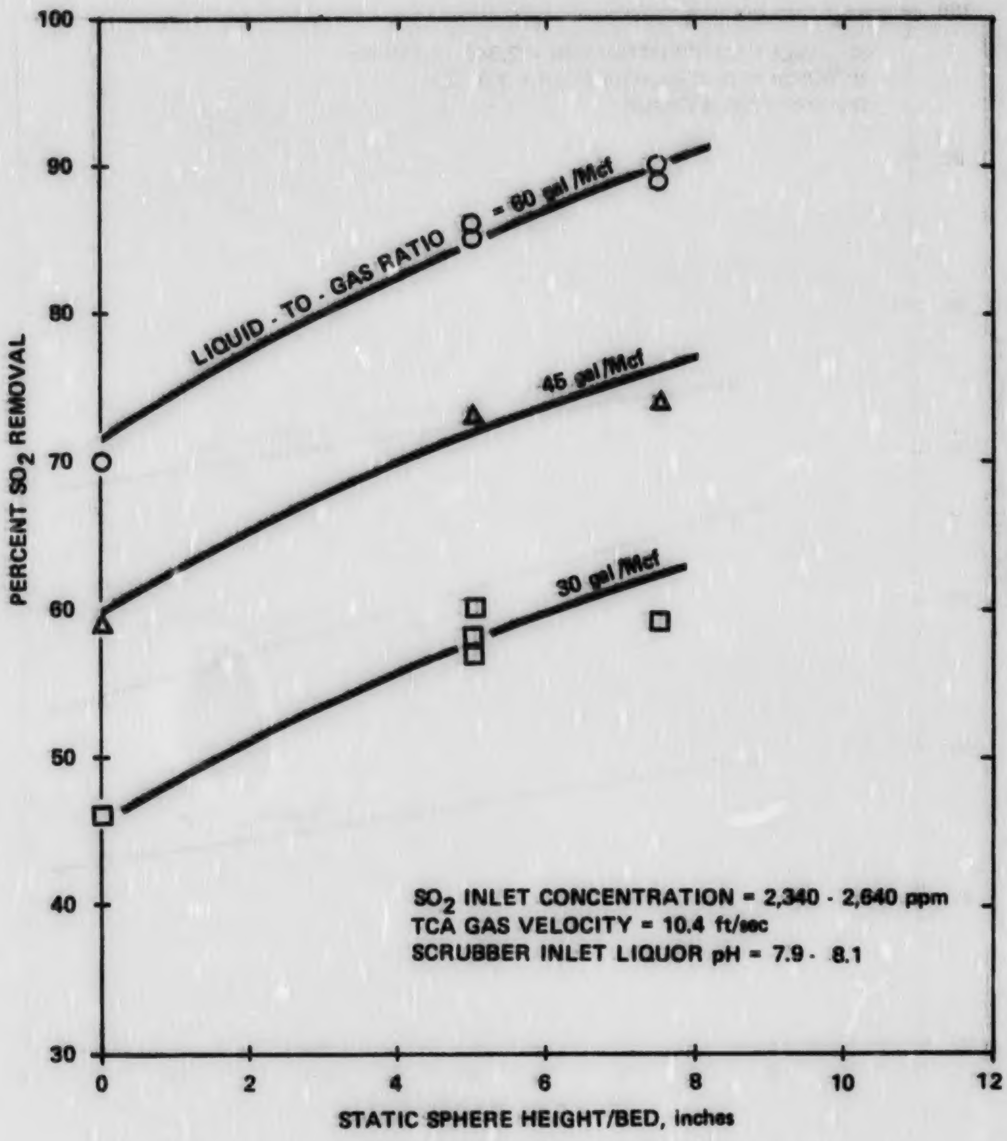

Figure 9-10. Effect of Sphere Bed Height and Liquid-to-Gas Ratio on SO_2 Removal - Three-Bed TCA with Lime

9.3 LIMESTONE TESTING WITH MAGNESIUM OXIDE ADDITION

Adding MgO to alkali scrubbing systems has been shown to increase SO_2 removal (Reference 4). The chemistry of magnesium addition is discussed in Subsection 5.3*. To determine the quantitative effect of MgO addition on SO_2 removal in the TCA, 51 limestone/MgO factorial tests were made. Test results are presented in Table 9-3. Independent variables tested with the TCA limestone/MgO system were:

- Gas flow rate
- Slurry recirculation rate
- Scrubber inlet liquor pH
- Sphere bed height
- Effective magnesium ion concentration in the recirculating liquor

Figure 9-11 shows the enhancement in SO_2 removal with increased effective liquor magnesium ion concentration and slurry flow rate for operation with three 5-inch beds of spheres. These effects are similar for the spray tower with MgO addition (compare Figure 6-19).

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* As explained there, only magnesium ions in stoichiometric excess of the chloride ions present are effective in increasing SO_2 removal. Effective magnesium, $(Mg)_e$, used when discussing MgO addition, is thus defined as $(Mg^{++} - Cl^- /2.92)$ if $Mg^{++} > Cl^- /2.92$, or as zero if $Mg^{++} \leq Cl^- /2.92$.

Table 9-3

SUMMARY OF LIMESTONE/MgO FACTORIAL TESTS ON THE TCA

Run Number	Gas Rate, acfm	Liquor Rate, gpm	Gas Vel., ft/sec	L/G, gal/Mcf	Total Sphere Height, in.	Bed Press. Drop, in. H_2O	Scrubber Inlet Liquor pH		Scrubber Outlet Liquor pH	Av. Scrubber Inlet Liquor Mg^{++} Conc., ppm	Av. Scrubber Inlet Liquor Cl^- Conc., ppm	Effective Mg^{++} Conc., ppm	Inlet SO_2 Conc., ppm		Percent SO_2 Removal		Replicate Number
							Range	Avg.					Range	Avg.	Range	Avg.	
TMG101	25000	900	10.4	45	15.0	5.6	5.48-5.62	5.55	--	2054	18470	0	2300-2400	2380	72-75	76	
TMG102	25000	1200	10.4	60	15.0	6.4	5.41-5.46	5.44	--	1910	21210	0	2480-2560	2530	77-80	79	
TMG103	25000	600	10.4	30	15.0	5.0	5.44-5.56	5.49	--	1896	20650	0	2480-2600	2540	62-65	64	
TMG104	30000	900	12.5	37	15.0	7.4	5.49-5.60	5.55	--	2041	21075	0	2280-2560	2443	79-82	80	
TMG105	25000	900	10.4	45	15.0	5.8	5.11-5.22	5.16	--	2071	13520	0	2360-2520	2425	60-66	64	A
TMG106	25000	1200	10.4	60	15.0	6.8	5.15-5.26	5.20	--	2168	13930	0	2480-2560	2511	72-75	74	
TMG107	25000	600	10.4	30	15.0	5.1	5.20-5.24	5.22	4.72	2142	13550	0	2360-2440	2409	56-57	56	
TMG108	25000	900	10.4	45	15.0	5.8	5.16-5.23	5.19	--	2075	14210	0	2400-2440	2429	66-68	67	A
TMG109	25000	900	10.4	45	15.0	5.9	5.73-5.78	5.76	5.25	2017	14090	0	2400-2600	2517	84-86	85	
TMG119	25000	900	10.4	45	15.0	5.8	5.45-5.56	5.51	--	4822	14075	1	2520-2640	2580	73-77	74	
TMG120	30000	900	12.5	37	15.0	7.5	5.46-5.58	5.52	--	4806	13970	21	2560-2600	2577	74-79	77	
TMG121	25000	900	10.4	45	15.0	5.7	5.17-5.30	5.23	--	4820	13000	367	2520-2720	2614	58-62	60	B
TMG122	25000	900	10.4	45	15.0	5.5	5.71-5.89	5.80	--	4685	13000	232	2420-2560	2467	78-84	80	
TMG138	20000	900	8.4	56	15.0	4.5	5.42-5.53	5.49	5.09	5227	13850	483	2320-2480	2406	69-72	71	
TMG151	25000	1200	10.4	60	15.0	6.0	5.47-5.60	5.52	--	4932	13600	274	2540-2560	2553	75-82	77	
TMG152	25000	600	10.4	30	15.0	4.9	5.47-5.60	5.51	--	5092	13600	434	2240-2480	2413	52-57	56	
TMG153	25000	900	10.4	45	15.0	5.7	5.15-5.34	5.24	--	5233	13500	609	2280-2440	2326	54-62	58	B
TMG154	25000	1200	10.4	60	15.0	6.6	5.17-5.32	5.23	--	5387	12900	969	2360-2400	2389	67-72	69	
TMG155	25000	600	10.4	30	15.0	4.9	5.10-5.26	5.19	--	5238	13400	648	2320-2400	2355	40-51	46	
TMG156	25000	900	10.4	45	0.0	2.0	5.20-5.30	5.25	--	5263	11770	1232	3000-3120	3064	46-51	49	
TMG157	25000	900	10.4	45	0.0	2.0	5.39-5.57	5.51	--	5078	10650	1430	3080-3160	3126	53-60	57	
TMG158	25000	900	10.4	45	0.0	2.0	5.80-5.87	5.84	--	4158	9638	857	3040-3280	3168	67-68	67	
TMG159	25000	900	10.4	45	0.0	1.9	5.44-5.59	5.49	--	8970	13064	4496	3000-3280	3176	62-66	65	C
TMG160	25000	900	10.4	45	0.0	2.0	5.17-5.30	5.23	--	9114	14334	4205	2000-2480	2167	67-70	69	
TMG161	25000	900	10.4	45	0.0	1.9	5.73-5.83	5.79	--	9805	13242	5270	2600-3040	2808	71-79	75	
TMG162	25000	1200	10.4	60	0.0	2.7	5.50-5.54	5.52	4.97	9719	12965	5278	3200-3600	3330	79-81	80	
TMG163	25000	600	10.4	30	0.0	1.5	5.39-5.59	5.48	--	8954	12376	4715	3040-3640	3383	53-60	57	
TMG164	25000	900	10.4	45	0.0	2.0	5.44-5.67	5.56	--	9467	11766	5437	3320-3580	3560	61-67	64	C
TMG165	25000	900	10.4	45	15.0	5.6	5.50-5.54	5.52	--	9638	13100	4951	2520-2600	2550	80-84	82	D
TMG166	30000	900	12.5	37	15.0	7.2	5.49-5.59	5.53	--	9161	14100	4332	2600-2640	2632	85-87	86	E
TMG167	25000	900	10.4	45	15.0	5.8	5.20-5.34	5.26	--	9377	15700	4000	2360-2480	2456	74-79	77	
TMG168	20000	900	8.4	56	15.0	4.5	5.48-5.55	5.51	--	8946	15400	3672	2200-2240	2213	84-87	86	
TMG169	25000	900	10.4	45	15.0	5.7	5.76-5.81	5.78	--	8821	14800	3752	2240-2280	2246	91-92	91	
TMG170	25000	900	10.4	45	15.0	5.8	5.47-5.60	5.53	--	9446	15000	4309	2100-2240	2180	85-89	87	D
TMG171	30000	900	12.5	37	15.0	8.5	5.36-5.62	5.50	4.98	9566	16170	4028	2160-2360	2225	88-92	90	E
TMG172	25000	900	10.4	45	15.0	5.6	5.68-5.95	5.78	--	13232	14380	8307	2320-2360	2347	97-98	97	F
TMG173	25000	900	10.4	45	15.0	5.9	5.40-5.59	5.51	--	12821	13500	8197	2100-2400	2313	95-97	96	G
TMG174	25000	1200	10.4	60	15.0	6.7	5.43-5.60	5.52	--	13005	12434	8746	2280-2400	2345	96-98	97	
TMG175	25000	600	10.4	30	5.0	4.6	5.46-5.48	5.47	--	14113	12957	9682	2200-2300	2280	74-77	76	
TMG176	30000	900	12.5	37	5.0	6.9	5.40-5.59	5.49	--	14060	--	9614	2320-2360	2336	91-95	94	
TMG177	25000	900	10.4	45	5.0	5.5	5.21-5.27	5.24	--	13104	12250	8915	2360-2400	2367	87-89	88	
TMG178	25000	1200	10.4	60	5.0	6.5	5.14-5.29	5.22	4.99	13065	16819	7313	2360-2400	2380	90-94	92	
TMG179	25000	600	10.4	30	5.0	4.8	5.09-5.34	5.20	--	12695	15175	7505	2320-2400	2376	67-77	72	
TMG180	25000	900	10.4	45	5.0	5.6	5.74-5.85	5.81	--	11636	14209	6777	2200-2240	2234	94-95	95	F
TMG181	25000	900	10.4	45	0	1.9	5.73-5.80	5.76	--	12475	13206	7959	2640-2700	2680	79-82	81	H
TMG182	25000	900	10.4	45	0	2.2	5.48-5.58	5.53	5.22	12925	13246	8395	2120-2480	2260	73-82	78	
TMG183	25000	900	10.4	45	0	2.0	5.15-5.28	5.22	4.92	13538	14413	8609	2600-2860	2683	71-77	74	
TMG184	25000	900	10.4	45	5.0	5.7	5.40-5.66	5.54	--	12318	14733	7279	2440-2520	2480	89-95	92	G
TMG185	30000	600	12.5	25	5.0	6.0	5.42-5.54	5.48	5.07	14215	15943	8762	2300-2540	2420	85-90	86	
TMG186	25000	900	10.4	45	0	2.0	5.70-5.85	5.80	5.40	13679	14057	8872	2640-3000	2847	86-87	87	H
TMG187	25000	900	10.4	45	0	2.0	5.42-5.52	5.47	--	9625	13905	4869	2000-2260	2155	70-74	72	C

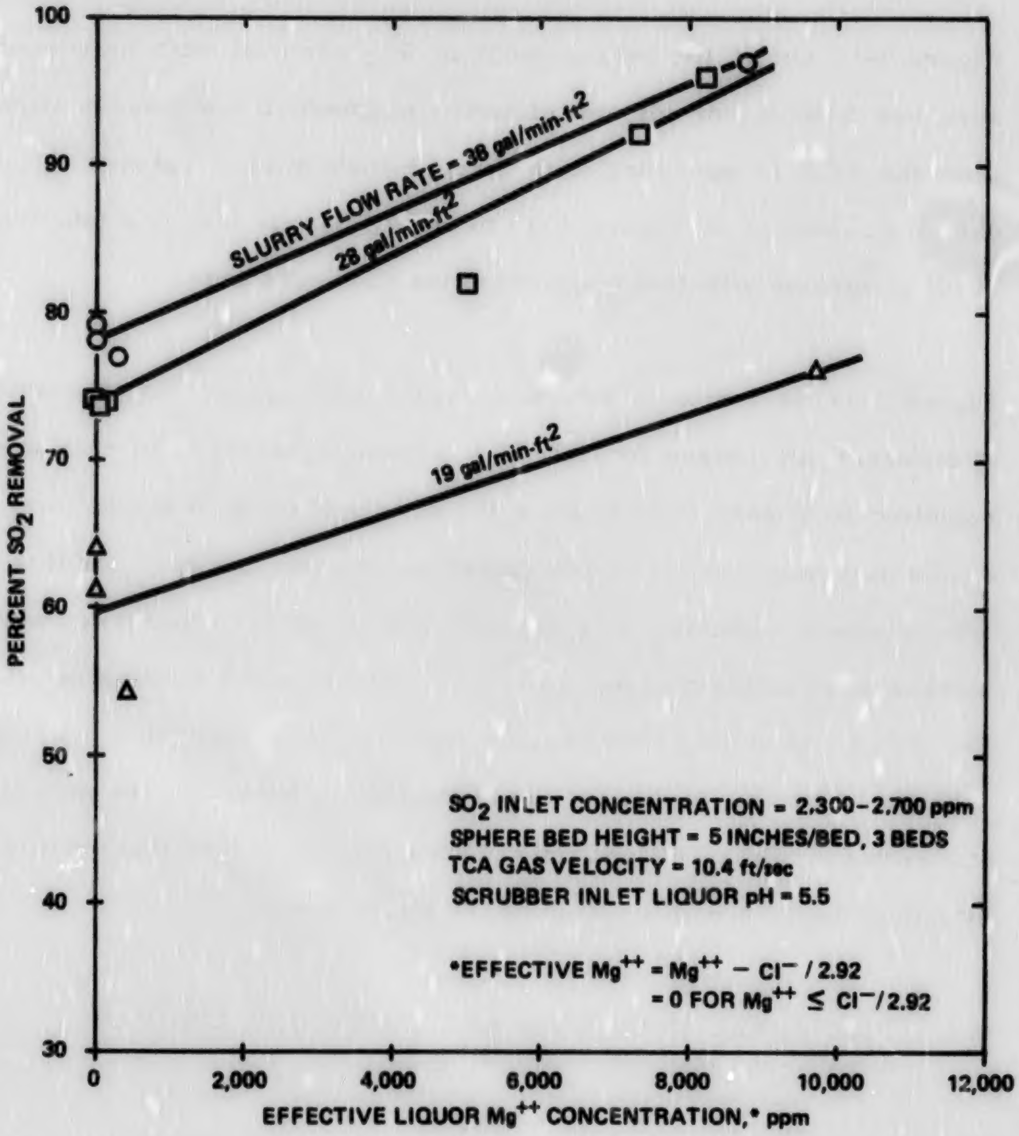

Figure 9-11. Effect of Effective Magnesium and Slurry Flow Rate on SO_2 Removal - TCA with Limestone

Figure 9-12 shows the enhancement in SO_2 removal with increased scrubber inlet liquor pH and effective magnesium ion concentration when the TCA is operating with three 5-inch beds of spheres. The data are replotted in Figure 9-13 to show SO_2 removal as a function of pH at various effective magnesium ion concentrations.

Figure 9-14 is a plot of effective magnesium versus SO_2 removal at different pH values for the TCA without spheres. The data are replotted in Figure 9-15 to show the effects of pH at different levels of effective magnesium ion concentration. As was the case for three 5-inch beds of spheres, SO_2 removal with no spheres increases with increasing effective magnesium ion concentration and increasing pH. The effect of adding magnesium for the TCA (with and without spheres) is similar to that for the spray tower. However, the percent SO_2 removed in the TCA without spheres was lower than that obtained by either the TCA with spheres or the spray tower.

9.4 COMPARISON OF LIME AND LIMESTONE ADDITION FOR ALL THREE SCRUBBERS

Figure 9-16 shows the increase in percent SO_2 removal with increasing pH for the TCA, spray tower, and venturi scrubbers using lime and limestone under selected run conditions. The run conditions used are presented in Table 9-4. Because of differing liquid-to-gas ratios, the results are not directly comparable for the three scrubbber types,

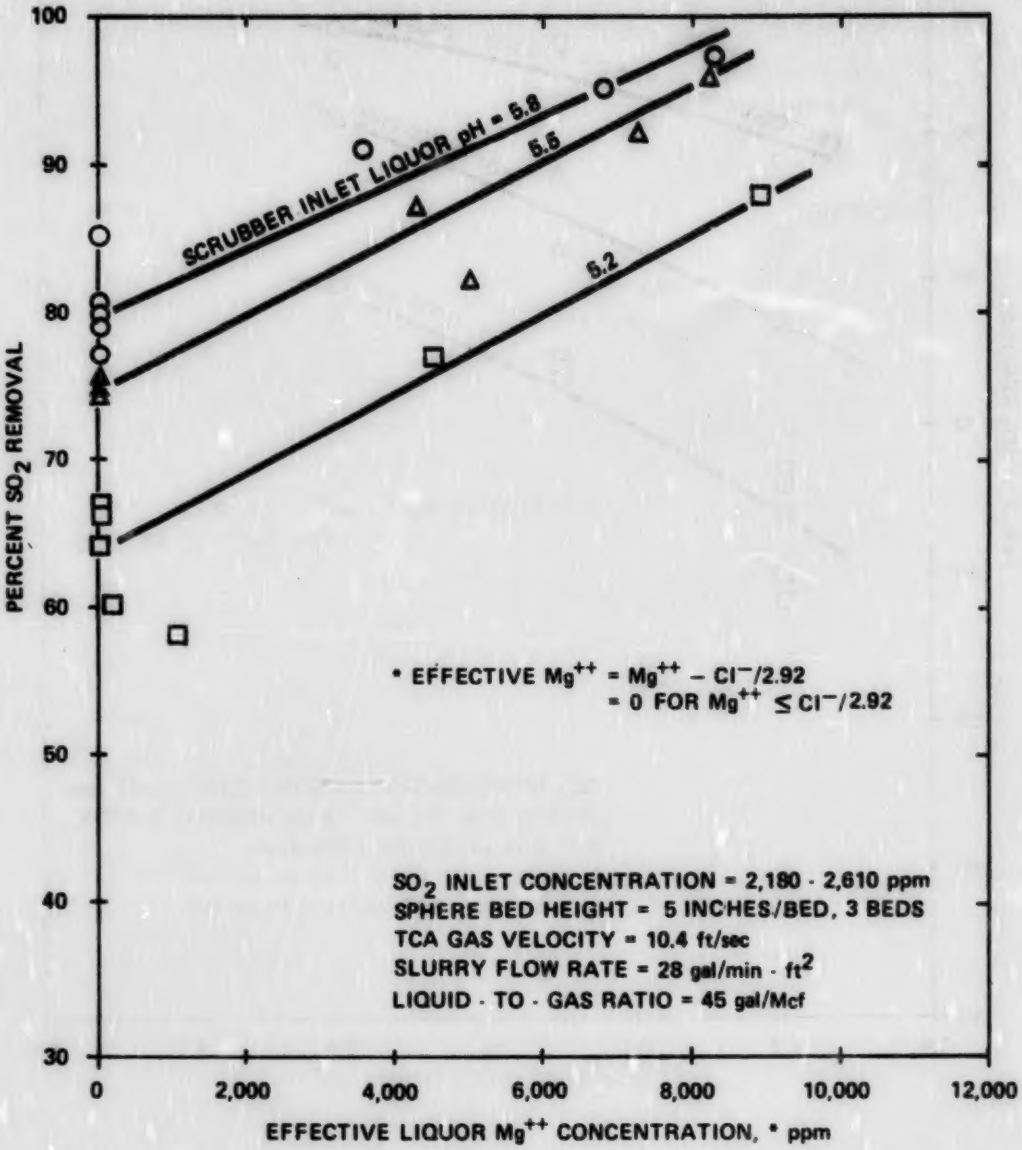

Figure 9-12. Effect of Effective Magnesium and Scrubber Inlet Liquor pH on SO_2 Removal - TCA with Limestone

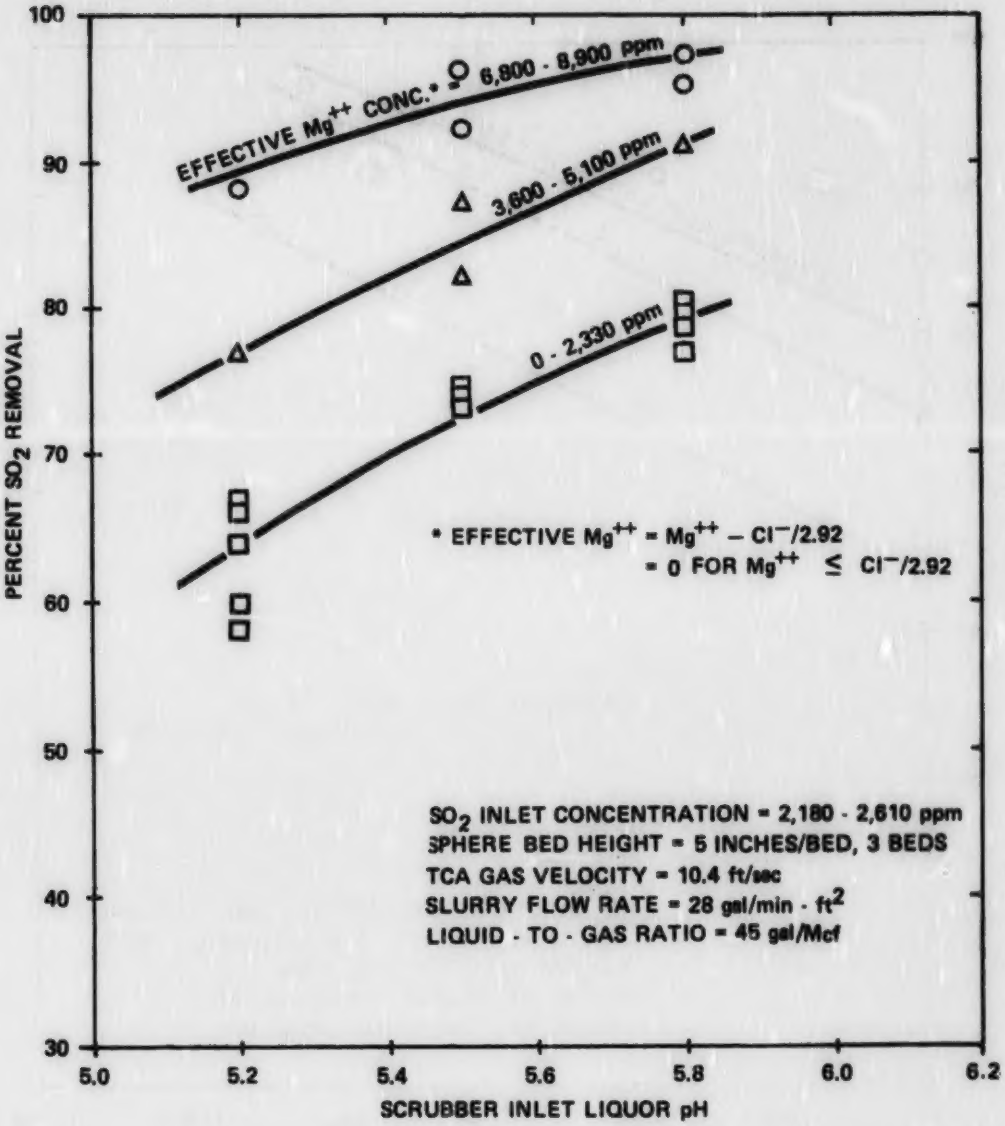

Figure 9-13. Effect of Scrubber Inlet Liquor pH and Effective Magnesium on SO_2 Removal - TCA with Limestone

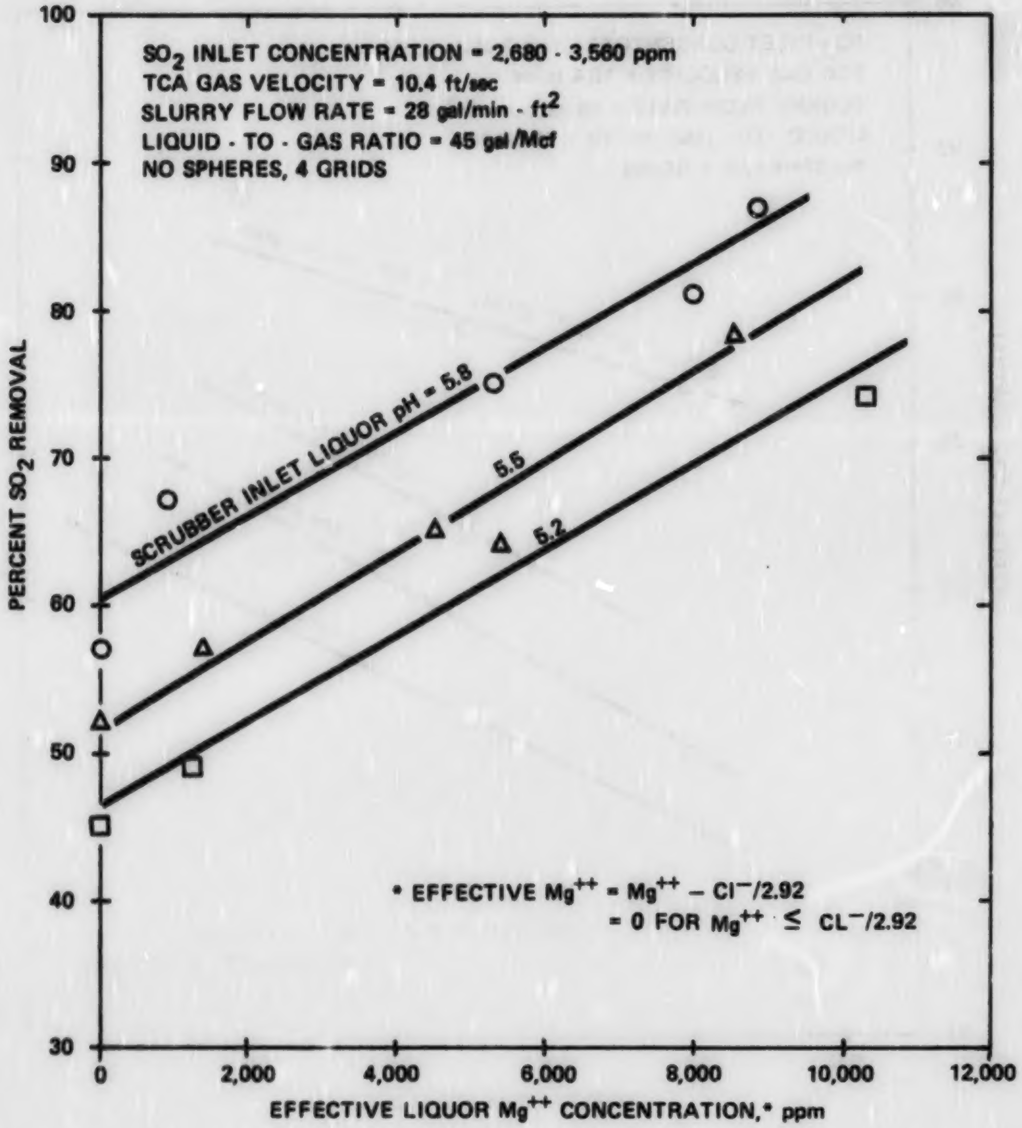

Figure 9-14. Effect of Effective Magnesium and Scrubber Inlet Liquor pH on SO_2 Removal - TCA (No Spheres) with Limestone

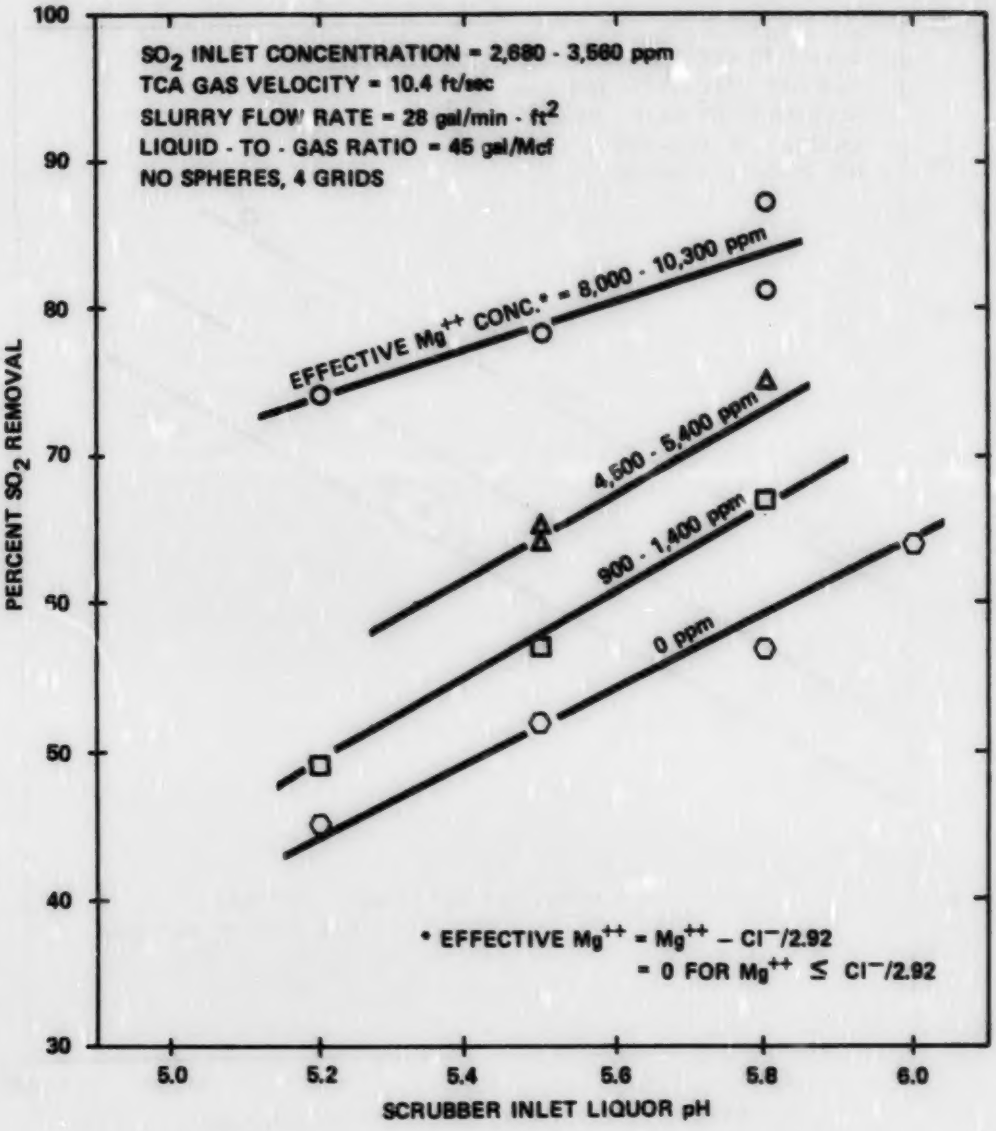

Figure 9-15. Effect of Scrubber Inlet Liquor pH and Effective Magnesium on SO_2 Removal - TCA (No Spheres) with Limestone

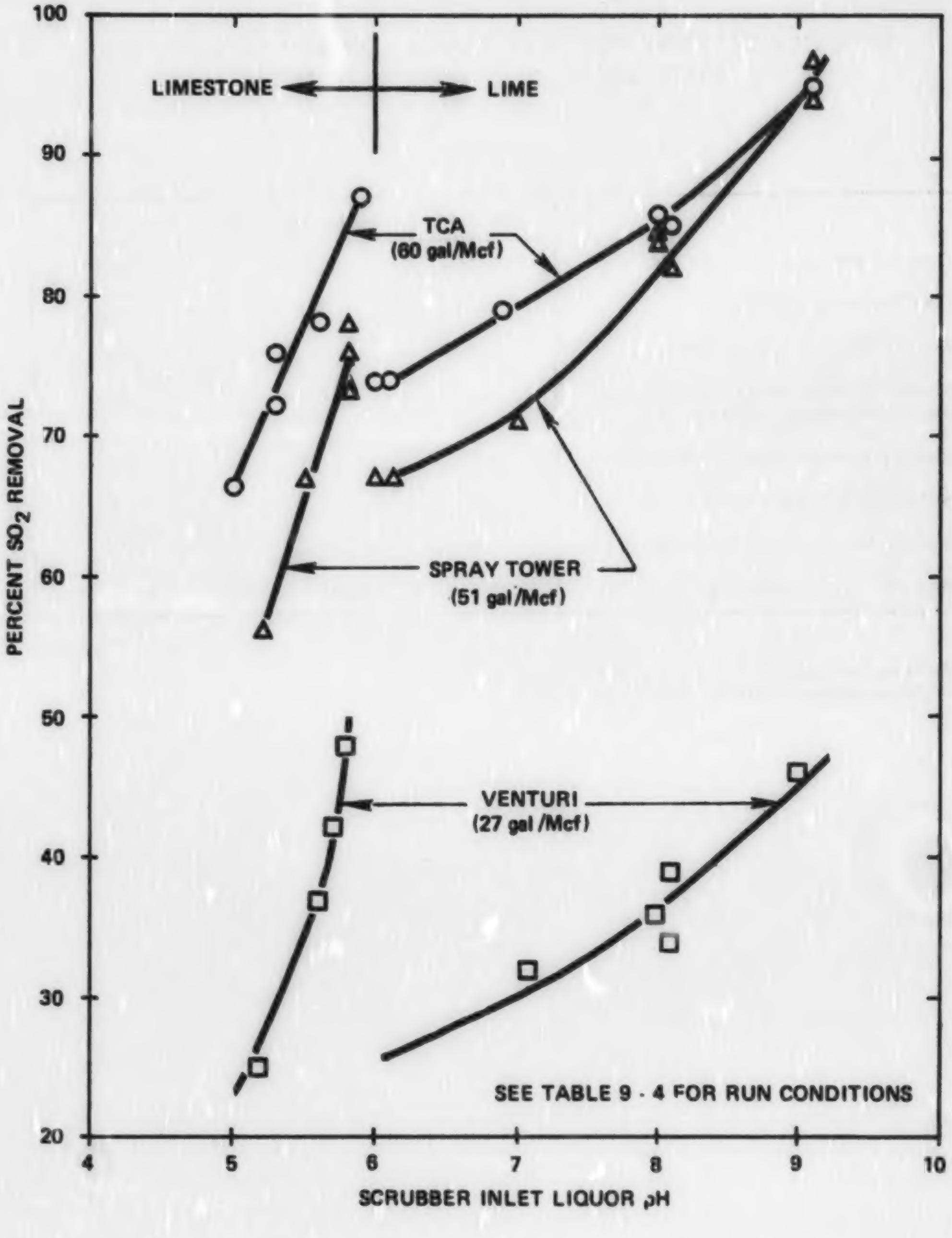

Figure 9-16. Effect of Scrubber Inlet Liquor pH on SO_2 Removal - Lime and Limestone Slurries

Table 9-4

RUN CONDITIONS FOR FACTORIAL TESTS COMPARING LIME AND LIMESTONE RESULTS

	TCA*	Spray Tower**	Venturi
Gas Flow Rate, acfm @ 300°F	25,000	27,500	27,500
Gas Velocity, ft/sec	10.4	7.4	--
Slurry Flow Rate, gal/min	1,200	1,125	600
Slurry Flow Rate per Unit Cross-sectional Area, gal/min-ft^2	38	22.5	--
Liquid-to-Gas Ratio, gal/Mcf	60	51	27
Scrubber Pressure Drop, in. H_2O	6	1	9
Slurry Solids Concentration, wt %	15	15	15
Inlet SO_2 Concentration, ppm	2,300-2,800	2,500-3,100	2,400-2,900

*Sphere bed height = 5 inches/bed, three beds
**Three spray banks in operation (1, 3, 4)

but the lime and limestone operating ranges for a given scrubber can be compared.

For all three scrubbers, SO_2 removal using limestone at pH 5.8 is greater than SO_2 removal using lime at pH 6 to 7. Lime at pH 8 is more effective than limestone at pH 5.8 for the spray tower, less effective for the venturi, and about as effective for the TCA.

The main reason for the lower SO_2 removal with lime at pH 6 to 7 is the very low lime stoichiometry (nearly 100 percent utilization). This low stoichiometry (i.e., low alkali solids concentration in the recirculated slurry) reduces the alkali dissolution rate in the scrubber, thus inhibiting SO_2 removal. On the other hand, SO_2 removal by limestone at pH 5.8 is relatively high because considerable excess limestone is required to maintain this pH, and therefore the limestone dissolution rate in the scrubber is high. Since this excess limestone must ultimately be discarded, the improved SO_2 removal relative to lime is achieved at the expense of higher limestone and sludge disposal costs.

In order for the lime system to have SO_2 removals as high as those for limestone, the lime system pH should be about 7.5-8.5, as indicated by the figure. This still gives a reasonably good alkali utilization of about 85-90 percent. Lime system operation above a pH of 8.5 is not recommended because of potential sulfite/carbonate scaling problems.

Section 10

TCA LIMESTONE TEST RESULTS

The TCA system was operated from mid-April through the end of June 1976 with flue gas containing fly ash while using limestone slurry. A total of eight test runs were made during this period, with an average of about 180 operating hours per run. With the exception of one run, these tests were made with MgO addition.

Performance data and test evaluations for each run are presented in this section, along with a table of major test conditions and selected results. A log of the scrubber operating periods is given in Appendix B. Properties of coal, limestone, and MgO used during these tests can be found in Appendix C. Appendix D presents a computer-tabulated summary of analytical data. Detailed test conditions and results are summarized in Appendix H. Selected operating data are graphically presented in Appendix I. Average scrubber inlet liquor compositions and the corresponding calculated percent gypsum saturations are given in Appendix J.

10.1 LIMESTONE/MgO TESTING WITH FLUE GAS CONTAINING FLY ASH

TCA Run 583-2B and Runs 584-2A through 589-2A were made using limestone slurry with added MgO. These tests were preceded by Run 583-2A, which was made without MgO addition to provide a base case for comparison. During part of Run 584-2A and all of Runs 585-2A and 586-2A, the centrifuge had to be taken out of service to rebuild worn out parts and the clarifier by itself was used as a solids dewatering device. Because of poor control of the clarifier underflow during this period, the system discharge solids contents ranged from 32 to 38 percent resulting in a less tight liquor loop operation than normal.

Table 10-1 lists the major test conditions and selected results for these runs. The objective of the tests made during this test block was to investigate the effect of adding MgO on percent SO_2 removal, sulfite oxidation, and liquor gypsum saturation in a limestone scrubbing system. An evaluation and a discussion of each test are presented below.

10.1.1 TCA Limestone Run 583-2A and Limestone/MgO Run 583-2B

The major test conditions for Runs 583-2A and 583-2B are given in Table 10-1. Three beds (four grids) were installed in the TCA, each

Table 10-1

MAJOR TEST CONDITIONS AND SELECTED RESULTS OF TCA LIMESTONE TESTING WITH MgO ADDITION

Major Test Conditions	583-2A(5)	583-2B(5)	584-2A	585-2A(5)	586-2A	587-2A	588-2A	589-2A
MgO addition	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fly ash	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gas rate, acfm	30,000	30,000	30,000	30,000	30,000	30,000	20,500	30,000
Liquor rate, gpm	1200	1200	1200	900	1200	1200	1200	1200
Percent solids recirculated	15	15	15	15	15	8	15	15
Effluent residence time, min	3.0	3.0	4.1(1)	4.1	4.1	4.1	4.1	4.1
Scrubber inlet liquor pH (controlled)(2)	---	---	---	---	---	---	---	5.4
Stoich. ratio (controlled), moles Ca/mole SO_2 absorbed	1.2	1.2	1.2	1.2	1.2	1.2	1.2	---
Effective Mg^{++} concentration, ppm	0	5000	9000	9000	9000	9000	9000	9000
Sphere height per bed (3 beds), inches	5	5	5	5	0	5	5	5
Selected Results								
On stream hours	131	230	236	140	110	295	107	200
Percent SO_2 removal	77	84	94	85	80	93	94	90
Inlet SO_2 concentration, ppm	3050	2900	2950	2900	2750	3100	2550	3600
SO_2 make-per-pass, m-moles/liter	12.5	13.5	15.0	17.5	12.0	15.0	8.5	16.0
Scrubber inlet liquor $SO_3^=$ concentration, ppm(3)	300	2780	8000	4190	7050	6300	3300	3700
Limestone utilization, 100x moles SO_2 absorbed/mole Ca added	80	77	77	77	83	74	53	80
Scrubber inlet liquor percent gypsum saturation @ 50°C	145	110	50	105	70	125	125	120
Percent sulfite oxidation	34	30	20	28	23	28	31	15
Scaling	---	Yes	No	Yes	No	Yes	---	Yes
Mist eliminator restriction, percent(4)	2	1	4	4	5	2	---	2

Notes:

1) Effluent residence time was 3.0 minutes for the first 80 hours of Run 584-2A.
2) Average scrubber inlet pH ranged from 5.3 to 5.5 for all runs.
3) Total sulfite includes $SO_3^=$ and HSO_3^-.
4) The mist eliminator was not cleaned prior to each run except for Run 583-2A.
5) Runs 583-2A, 583-2B, and 585-2A had suspected air leakage in the scrubber downcomer.

bed containing nitrile foam spheres nominally 1-1/2 inch diameter to a static depth of 5 inches. Other detailed operating conditions can be found in Appendix H.

The test conditions for Run 583-2B were the same as for Run 583-2A, except that MgO was dry-fed to the effluent hold tank to maintain an effective magnesium ion concentration of 5000 ppm in the scrubbing liquor. The centrifuge was used as a solids dewatering device during Run 583-2B (cf. clarifier during Run 583-2A) to maintain a tighter liquor loop to minimize MgO consumption. MgO addition during Run 583-2B was about 1.6 lb of MgO per 100 lb of $CaCO_3$.

Runs 583-2A and 583-2B were conducted to compare the percent SO_2 removals, sulfite oxidations, and liquor gypsum saturations with and without MgO addition. A limestone stoichiometry of 1.2 moles of Ca per mole of SO_2 absorbed (about 85 percent utilization) was maintained to obtain a reliable mist eliminator operation (see Reference 3). The scrubber system, including the mist eliminator, was cleaned before Run 583-2A. No cleaning was done prior to Run 583-2B.

As expected, higher percent SO_2 removal was achieved during Run 583-2B when MgO was added. The SO_2 removal averaged 84 percent at an average inlet SO_2 concentration of 2900 ppm during Run 583-2B, compared with 77 percent removal at 3050 ppm for Run 583-2A. Average gypsum saturation in the scrubber inlet liquor was 145 percent for Run 583-2A versus 110 percent for Run 583-2B. Average sulfite oxidation* decreased slightly from 34 to 30 percent when MgO was added. Sulfite (including bisulfite) concentration in the scrubber inlet liquor averaged only 300 ppm for Run 583-2A and 2780 ppm for Run 583-2B. The mist eliminator was 2 percent and 1 percent restricted by soft solids at the end of Runs 583-2A and 583-2B, respectively. Some scale was observed in the lower part of the scrubber at the end of Run 583-2B.

10.1.2 TCA Limestone/MgO Run 584-2A

The test conditions for Run 584-2A were similar to those in Run 583-2B, except that the effective magnesium ion concentration in the scrubbing liquor was raised from 5000 to 9000 ppm to further observe its effect on SO_2 removal, sulfite oxidation, and liquor gypsum saturation.

At 9000 ppm effective magnesium ion concentration and a solids concentration range of 35 to 65 percent in the sludge discharged from the system (during Runs 584-2A through 589-2A), the MgO requirement was about 2 to 6.5 lb of MgO per 100 lb of $CaCO_3$.

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* During the ten-week boiler maintenance outage in April-June 1977, it was discovered that the scrubber downcomer discharged 14 ft. from the bottom of the effluent hold tank (D-204). Runs 583-2A, 583-2B, and 585-2A were inadvertently made with hold tank levels less than 14 ft. Therefore, these runs had suspected air leakage into the scrubber downcomer and consequently higher sulfite oxidation and gypsum saturation.

The mist eliminator was not cleaned prior to Run 584-2A. After about 80 hours of operation, the effluent hold tank residence time was increased from 3 to 4.1 minutes to minimize the fluctuations in the scrubber inlet pH and to help reduce caking of MgO solids on the tank walls and the agitator shaft.

For Run 584-2A, average SO_2 removal increased to 94 percent, compared with 84 percent for Run 583-2B, at an average inlet SO_2 concentration of about 2900 ppm. Sulfite oxidation* decreased from 30 to 20 percent, and scrubber inlet liquor gypsum saturation decreased from 110 to 50 percent. Sulfite concentration in the scrubber inlet liquor increased almost threefold from 2780 to 8000 ppm.

The mist eliminator was 4 percent restricted at the end of Run 584-2A. Scale that had formed during Run 583-2B in the lower part of the scrubber was diminishing by the end of Run 584-2A. There was a heavy solids buildup in the flue gas outlet duct.

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* See footnote on Page 10-5.

10.1.3 TCA Limestone/MgO Run 585-2A

The slurry flow rate for Run 585-2A was reduced to 900 gpm (37 gal/Mcf), compared with 1200 gpm (50 gal/Mcf) for Run 584-2A. The effluent residence time, which had been increased from 3 to 4.1 minutes during Run 584-2A, remained at 4.1 minutes for Run 585-2A. Other test conditions for the two runs were the same.

The objectives of Run 585-2A were to determine whether SO_2 could be satisfactorily removed at the lower slurry flow rate and at 9000 ppm effective magnesium ion concentration and to observe the levels of sulfite oxidation and gypsum saturation. This run provides data for calculating the tradeoff between the costs of magnesium and the cost of slurry pumping energy. The mist eliminator was not cleaned prior to Run 585-2A.

Run 585-2A yielded a satisfactory average SO_2 removal of 85 percent, but sulfite oxidation* increased to 28 percent, compared with 20 percent for Run 584-2A. Gypsum saturation in the scrubber inlet liquor increased to 105 percent from 50 percent for Run 584-2A. The mist eliminator was 4 percent restricted by solids at the end of Run 585-2A, a value unchanged from the beginning of the run. There was, however, a slight gain in scale on the scrubber walls below the bottom grid.

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* See footnote on page 10-5.

10.1.4 TCA Limestone/MgO Run 586-2A

For Run 586-2A, all nitrile foam spheres in the three TCA beds were removed, leaving only four bar-grids in the scrubber. Other test conditions were the same as for Run 584-2A.

The purpose of Run 586-2A was to observe if SO_2 could be satisfactorily removed by a "grid" tower at 9000 ppm effective magnesium ion concentration. This run provides data for calculating the tradeoff between the cost of magnesium and the costs of TCA spheres and flue gas fan energy. The mist eliminator was not cleaned before Run 586-2A. The SO_2 removal averaged 80 percent at an average inlet SO_2 concentration of 2750 ppm, compared with 94 percent removal at 2950 ppm for Run 584-2A. Average sulfite oxidation was 23 percent, and gypsum saturation in the scrubber inlet liquor was 70 percent for Run 586-2A, as opposed to 20 percent oxidation and 50 percent saturation for Run 584-2A. Average scrubber inlet pH was 5.3 at 83 percent limestone utilization for Run 586-2A versus 5.4 inlet pH at 77 percent utilization for Run 584-2A.

The mist eliminator was 5 percent restricted by solids at the end of Run 586-2A, a slight increase from 4 percent at the start of the run. Scale deposits in the lower parts of the scrubber remained nearly the same as at the beginning of the run.

10.1.5 TCA Limestone/MgO Run 587-2A

Run 587-2A test conditions were similar to those for Run 584-2A, except that percent solids in the recirculated slurry was reduced from 15 to 8 percent to observe the effect on liquor gypsum saturation. The mist eliminator was not cleaned prior to Run 587-2A. Nitrile foam spheres removed before Run 586-2A were reinstalled. The test was interrupted for about 30 hours by a Boiler No. 10 maintenance outage.

Average gypsum saturation in the scrubber inlet liquor was 125 percent for Run 587-2A, considerably higher than the 50 percent during Run 584-2A. Sulfite oxidation for Run 587-2A was also higher at 28 percent, compared with 20 percent for Run 584-2A. Other test results for the two runs were approximately the same. During Run 587-2A, the mist eliminator restriction by solids decreased from 5 to 2 percent. Scrubber walls below the bottom grid gained scale during Run 587-2A, as could be expected from the gypsum-supersaturated operation. The entrance of the downcomer to D-204 effluent hold tank was 75 percent plugged by scale and solids.

10.1.6 TCA Limestone/MgO Run 588-2A

The test conditions for Run 588-2A were similar to those for Run

584-2A, except that the flue gas flow rate was reduced from 30,000 to 20,500 acfm (scrubber gas velocity reduced from 12.5 to 8.6 ft/sec). The slurry flow rate was unchanged at 1200 gpm, resulting in an increased liquid-to-gas ratio from 50 to 73 gal/Mcf.

The objective of Run 588-2A was to observe the effect of higher liquid-to-gas ratio on liquor gypsum saturation and to compare the results with those of Run 584-2A. The mist eliminator was not cleaned at the start of the run. Before the run, the old nitrile foam spheres in the top and middle beds were replaced with new ones.

Gypsum saturation in the scrubber inlet liquor averaged 125 percent and sulfite oxidation 31 percent for Run 588-2A, compared with 50 percent saturation and 20 percent oxidation during Run 584-2A. Average SO_2 removal was 94 percent for both runs. However, limestone utilization averaged only 53 percent and inlet SO_2 concentration 2550 ppm for Run 588-2A, compared with 77 percent utilization and 2950 ppm SO_2 concentration for Run 584-2A. The scrubber was not inspected at the end of Run 588-2A.

10.1.7 TCA Limestone/MgO Run 589-2A

The test conditions for Run 589-2A were identical to those for Run 584-2A, except that the scruber inlet liquor pH during Run 589-2A was controlled at 5.4 whereas limestone stoichiometic ratio during Run 584-2A was controlled at 1.2 moles of Ca per mole SO_2 absorbed.

During Run 584-2A, the scrubber inlet slurry pH fluctuated between 5.1 and 5.7, with an average of 5.4, and the SO_2 removal varied from 90 to 98 percent. Therefore, Run 589-2A was intended to observe whether these wide variations could be minimized by a smoother, controlled scrubber inlet pH of 5.4. The mist eliminator was not cleaned prior to Run 589-2A.

Although a smoother scrubber inlet pH was obtained during Run 589-2A (5.3-5.6 versus 5.1-5.7 for Run 584-2A), the fluctuation in SO_2 removal (86 to 94 percent) was not reduced indicating that the pH effect might have been overshadowed by other factors, such as inlet SO_2 concentration and liquor sulfite concentration.

The test results from Runs 584-2A and 589-2A were quite different under seemingly identical operating conditions (see Table 10-1 for comparison). Average SO_2 removal was 90 percent and limestone utilization was 80 percent at average inlet SO_2 concentration of 3600 ppm during Run 589-2A, as compared with 94 percent SO_2 removal and 77 percent limestone utilization at 2950 ppm inlet SO_2 concentration for Run 584-2A. Gypsum saturation in the scrubber inlet liquor was higher for Run 589-2A at 120 percent (50 percent for Run 584-2A), with correspondingly lower liquor sulfite concentration ($SO_3^=$ and HSO_3^-) of 3700 ppm (8000 ppm for Run 584-2A).

The scubber walls below the bottom grid gained scale since the inspection at the end of Run 587-2A. However, the mist eliminator remained 2 percent restricted by solids. It had operated 1450 hours without cleaning since the beginning of Run 583-2A.

10.2 CONCLUSIONS

Eight test runs were made on the TCA system with flue gas containing fly ash and using limestone slurry. Of the eight runs, one was made without adding MgO, one with 5000 ppm effective liquor magnesium ion concentration, and the remainder with 9000 ppm effective magnesium ion concentration. The following conclusions were made from the results of these tests:

- Higher effective liquor magnesium ion concentration is needed in a limestone scrubbing system than in a lime scrubbing system to obtain a similar degree of improvement in SO_2 removal efficiency. This is probably due to the lower pH inherent in the limestone system, where the sulfite-bisulfite equilibrium favors a shift toward bisulfite, which is not an SO_2 scrubbing species
- At 0, 5000, and 9000 ppm effective magnesium ion concentrations (Runs 583-2A, 583-2B, and 584-2A), average SO_2 removals were 77, 84, and 94 percent, respectively, under typical operating conditions

- As in the case of lime scrubbing with added MgO (see Section 7), gypsum scaling occurred at scrubber inlet liquor gypsum saturations as low as 80 percent

- Satisfactory SO_2 removal was achieved at 9000 ppm effective magnesium ion concentration by operating at only 900 gpm (37 gal/Mcf) slurry flow rate (Run 585-2A) or by operating the TCA without spheres (Run 586-2A) -- a tradeoff between MgO cost and the costs of slurry pumping energy, spheres, and fan power

- Adding MgO at the levels tested did not always result in gypsum subsaturated operation. Conditions required to achieve consistent subsaturated operation have not yet been defined. However, lower saturation, when obtained, normally brought about higher liquor sulfite concentration and SO_2 removal efficiency

Section 11

TCA LIME TEST RESULTS

The TCA system was operated from July through November 1976, with lime slurry to scrub flue gas containing fly ash. A total of 18 runs were made during this period, with an average of about 160 operating hours per run. Of the 18 runs, 16 were made with MgO addition.

This section presents the performance data and test evaluations for each run, along with tables of major test conditions and selected results. A log of the scrubber operating periods is given in Appendix B. Properties of coal, lime, and MgO used during these tests can be found in Appendix C. A computer-tabulated summary of analytical data is given in Appendix D. Detailed operating conditions and test results are summarized in Appendix H. Selected operating data are graphically presented in Appendix I. Average scrubber inlet liquor compositions and the corresponding calculated percent gypsum saturations can be found in Appendix J.

11.1 LIME/MgO TESTING WITH FLUE GAS CONTAINING FLY ASH

TCA Runs 601-2A through 615-2A and Run 608-2B were conducted using lime slurry with added MgO. Table 11-1 lists the major test conditions and selected results for these runs. These tests were made to observe the effect of adding magnesium oxide on the SO_2 removal, sulfite oxidation, and liquor gypsum saturation in a TCA lime scrubbing system.* Average lime utilization for these runs ranged from 96 to 100 percent. At the two effective magnesium ion concentrations of 2000 and 4000 ppm used during these runs, average MgO consumption ranges were 1.4 to 2.2 and 2.5 to 3.2 lb of MgO per 100 lb of CaO, respectively. Average solids content in the system discharge sludge ranged from 54 to 63 percent for these runs. An evaluation and a discussion of each test are presented below.

11.1.1 TCA Lime/MgO Run 601-2A

Run 601-2A began on July 1 and ended on July 12, 1976, after 177 on-stream hours. The test was halted for about 1 day on July 3 by

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* It was discovered, during the ten-week boiler maintenance outage in April-June 1977, that the scrubber downcomer discharged 14 ft. from the bottom of the effluent hold tank D-204, which was used during most of these tests. Runs 604-2A, 606-2A through 608-2A, and 611-2A through 613-2A were inadvertently made with the hold tank levels less than 14 ft. Therefore, these runs had suspected air leakage into the scrubber downcomer and consequently higher sulfilte oxidation and gypsum saturation.

Table 11-1

MAJOR TEST CONDITIONS AND SELECTED RESULTS OF TCA LIME TESTING

Major Test Conditions[1]	601-2A	602-2A	603-2A	604-2A[5]	605-2A	606-2A[5]	607-2A[5]	608-2A[5]	608-2B
MgO addition	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fly ash	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gas rate, acfm	30,000	30,000	30,000	30,000	20,500	30,000	30,000	30,000	30,000
Liquor rate, gpm	1200	1200	1200	900	1200	900	900	900	900
Percent solids recirculated	8	15	8	8	8	8	8	15	15
Effluent residence time, min	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	5.4
Scrubber inlet liquor pH (controlled)	7.0	7.0	7.0	7.0	7.0	8.0	8.0	8.0	8.0
Effective Mg^{++} concentration, ppm	2000	2000	2000	2000	2000	2000	4000	4000	4000
Lime addition point[2]	DC	DC	EHT	DC	DC	DC	DC	DC	DC
Selected Results									
On stream hours	177	137	165	158	170	122	212	84	151
Percent SO_2 removal	92	88	84	73	80	76	86	83	95
Inlet SO_2 concentration, ppm	2900	3150	3350	3200	3500	3300	3200	3550	3100
SO_2 make-per-pass, m-moles/liter	13.5	14.5	14.0	17.5	10.5	17.5	20.0	21.5	22.0
Scrubber inlet liquor $SO_3^=$ concentration, ppm[3]	525	425	395	280	395	265	695	490	2780
Lime utilization, 100x moles SO_2 absorbed/mole Ca added	96	98	100	100	99	97	99	98	96
Scrubber inlet liquor percent gypsum saturation @ 50°C	50	40	75	90	45	95	75	95	11
Percent sulfite oxidation	14	14	20	28	20	24	15	20	12
Scaling	No	No	V. Slight	Yes	No	Yes	Yes	Yes	No
Mist eliminator restriction, percent[4]	<1	<1	3-5	40	1	10	[illegible]	---	2

Note: Footnotes for this table are listed in Table 11-1 (continued).

Table 11-1 (continued)

MAJOR TEST CONDITIONS AND SELECTED RESULTS OF TCA LIME TESTING

Major Test Conditions[1]	609-2A	610-2A	611-2A[5]	612-2A[5]	613-2A[5]	614-2A	615-2A	616-2A	617-2A
MgO addition	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Fly ash	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gas rate, acfm	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Liquor rate, gpm	900	900	900	900	1200	900	1200	1200	1200
Percent solids recirculated	8	8	8	6	8	8	8	8	15
Effluent residence time, min	5.4	5.4	4.1	3.0	3.0	16	12	12	12
Scrubber inlet liquor pH (controlled)	7.0	8.0	8.0	8.0	7.0	8.0	7.0	8.0	8.0
Effective Mg^{++} concentration, ppm	2000	2000	2000	2000	2000	2000	2000	0	0
Lime addition point[2]	DC	DC	DC	DC	DC	DC	DC	DC	DC
Selected Results									
On stream hours	259	280	111	139	67	139	110	174	159
Percent SO_2 removal	75	84	81	81	85	75	88	72	80
Inlet SO_2 concentration, ppm	3050	2950	2900	3050	3050	3650	3100	3300	3100
SO_2 make-per-pass, m-moles/liter	16.0	17.0	17.0	17.5	14.0	15.5	14.5	12.0	13.0
Scrubber inlet liquor $SO_3^=$ concentration, ppm[3]	430	670	300	300	280	345	305	140	125
Lime utilization, 100x moles SO_2 absorbed/mole Ca added	100	98	97	100	100	97	98	91	93
Scrubber inlet liquor percent gypsum saturation @ 50°C	60	40	95	95	95	90	95	115	110
Percent sulfite oxidation	18	7	30	32	35	12	17	20	12
Scaling	No	No	Yes	Yes	Yes	Yes	Slight	Slight	V. Slight
Mist eliminator restriction, percent[4]	3	2	6	5	12	4	2	<1	<1

Notes:

1) Three beds (4 grids) with nominal 5 inches spheres/bed for all runs.
2) Lime addition point: DC = scrubber downcomer, EHT = effluent hold tank.
3) Total sulfite includes $SO_3^=$ and HSO_3^-.
4) The mist eliminator was not cleaned prior to each run except Runs 605-2A, 607-2A, 608-2A, 612-2A, and 614-2A through 616-2A.
5) These runs had suspected air leakage in the scrubber downcomer.

a temporary interruption of lime supply, and again for about 2 days (July 4 to 6) by a Boiler No. 10 maintenance outage.

The major test conditions for the run are listed in Table 11-1. Three beds (four grids) were installed in the TCA, each bed containing 5 inches static height of nominal 1-1/2 inch diameter nitrile foam spheres. Fresh lime slurry was introduced into the scrubber downcomer. Other detailed operating conditions can be found in Appendix H.

The clarifier contents were dumped and the inside walls cleaned before the start of Run 601-2A. The mist eliminator was not cleaned before the run.

Average SO_2 removal for Run 601-2A was 92 percent at an average inlet SO_2 concentration of 2900 ppm. Sulfite oxidation averaged 14 percent and scrubber inlet liquor gypsum saturation averaged 50 percent. The SO_2 make-per-pass, i.e., number of moles of sulfur (SO_2 and SO_3) absorbed by a unit volume of scrubbing slurry as it makes one pass through the scrubber, averaged about 13.5 m-moles/liter. The mist eliminator was less than 1 percent restricted at the end of the run, a decrease from 2 percent at the start of the run.

11.1.2 TCA Lime/MgO Run 602-2A

The test conditions for Run 602-2A were the same as for Run 601-2A, except that the solids content in the recirculated slurry was increased from 8 to 15 percent to observe the effect on liquor gypsum saturation. The mist eliminator was not cleaned before the start of the run.

Average scrubber inlet liquor gypsum saturation was 40 percent, as opposed to 50 percent for Run 601-2A. Sulfite oxidation averaged 14 percent, the same as for Run 601-2A. Average SO_2 removal was 88 percent for Run 602-2A, compared with 92 percent for Run 601-2A. The SO_2 make-per-pass averaged 14.5 m-moles/liter, somewhat higher than the SO_2 make-per-pass of Run 601-2A because of the higher average inlet SO_2 concentration of 3150 ppm. The condition of the mist eliminator was unchanged and remained less than 1 percent restricted at the end of the run.

11.1.3 TCA Lime/MgO Run 603-2A

Run 603-2A was made under the same conditions as for Run 601-2A, except the fresh lime addition point was moved from the scrubber downcomer to the effluent hold tank to observe the effect on liquor gypsum saturation. The mist eliminator was not cleaned prior to the test.

Average gypsum saturation in the scrubber inlet liquor increased to 75 percent, compared with 50 percent for Run 601-2A. Sulfite oxidation averaged 20 percent versus 14 percent during Run 601-1A. Average SO_2 removal was 84 percent and SO_2 make-per-pass was 14 m-moles/liter at 3350 ppm average inlet SO_2 concentration for Run 603-2A, compared with 92 percent SO_2 removal and 13.5 m-moles/liter at 2900 ppm for Run 601-2A. The mist eliminator was 3 to 5 percent restricted at the end of the run.

11.1.4 TCA Lime/MgO Run 604-2A

Test conditions for Run 604-2A were the same as Run 601-2A, except that the slurry flow rate was reduced from 1200 to 900 gpm (liquid-to-gas ratio reduced from 50 to 37 gal/Mcf).

The objective of Run 604-2A was to investigate the effect of the lower liquid-to-gas ratio on the SO_2 removal and liquor gypsum saturation. The mist eliminator was not cleaned prior to the run.

At an average inlet SO_2 concentration of 3200 ppm, the SO_2 removal averaged only 73 percent, a substantial decrease from 92 percent at 2900 ppm during Run 601-2A. The SO_2 make-per-pass increased from 13.5 m-moles/liter for Run 601-2A to 17.5 m-moles/liter, and the scrubber inlet liquor gypsum saturation increased to 90 percent* from 50 percent for Run 601-2A. Sulfite oxidation was 28 percent,* twice the value for Run 601-2A. Gypsum scaling occurred within the scrubber, and the mist eliminator was 40 percent restricted by scale and solids.

11.1.5 TCA Lime/MgO Run 605-2A

Test conditions for Run 605-2A were the same as for Run 601-2A, except that the flue gas flow rate was reduced from 30,000 to 20,500 acfm (liquid-to-gas ratio increased from 50 to 73 gal/Mcf). The purpose of the run was to observe the effect of the higher liquid-to-gas ratio (and lower SO_2 make-per-pass) on the SO_2 removal and liquor gypsum saturation. The mist eliminator, outlet duct to reheater, bottom TCA grid, and scrubber walls below the bottom grid were cleaned prior to the run.

Average gypsum saturation in the scrubber inlet liquor was 45 percent and the SO_2 removal was 80 percent at 3500 ppm inlet SO_2 concentration, compared with 50 percent gypsum saturation and 92 percent SO_2 removal at 2900 ppm inlet SO_2 concentration for Run 601-2A. The SO_2 make-per-pass averaged 10.5 m-moles/liter and sulfite oxidation averaged 20 percent, as opposed to 13.5 m-moles/liter and 14 percent oxidation for Run 601-2A.

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* See footnote on page 11-2.

The mist eliminator was found to be only 1 percent restricted during an inspection at 151 operating hours. During this inspection, it was found that two of the four slurry distribution nozzles had been completely plugged by leftover scale and solids debris from the cleanup before the start of the run. After the plugged nozzles were cleaned, the run was continued under the same operating conditions. The SO_2 removal was found to be essentially unaffected by the plugged nozzles.

11.1.6 TCA Lime/MgO Run 606-2A

Run 606-2A followed Run 605-2A without a system shutdown. The test conditions for Run 606-2A* were the same as for Run 604-2A, except that the scrubber inlet liquor pH was raised from 7.0 to 8.0.

The objective of the run was to observe whether the TCA could be operated free of scaling at 900 gpm slurry flow rate (37 gal/Mcf) at the higher scrubber inlet pH. Severe scaling was encountered during Run 604-2A, despite the fact that gypsum saturation in the scrubber inlet liquor was only 90 percent. It was theorized that higher alkalinity (higher pH) in the scrubber inlet liquor might cause less calcium sulfite dissolution within the scrubber, thus less increase in the degree of gypsum saturation across the scrubber.

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* See footnote on page 11-2.

Average scrubber inlet liquor gypsum saturation was 95 percent, a slight increase from 90 percent during Run 604-2A. However, relative to Run 604-2A, there was less scale on both the scrubber walls and the scrubber outlet duct to the reheater. The mist eliminator was 10 percent restricted by scale and solids. The SO_2 removal averaged 76 percent at 3300 ppm average inlet SO_2 concentration for Run 606-2A, compared with 73 percent at 3200 ppm for Run 604-2A.

11.1.7 TCA Lime/MgO Run 607-2A

The test conditions for Run 607-2A were the same as for Run 606-2A except that the effective magnesium ion concentration in the liquor was raised from 2000 to 4000 ppm in a continuing effort to operate the TCA free of scaling at 900 gpm (37 gal/Mcf) slurry flow rate (see Runs 604-2A and 606-2A).*

The mist eliminator and the TCA bottom grid were cleaned prior to Run 607-2A. The test was interrupted for about 5 days by TVA inspections of corrosion and erosion test specimens and mechanical components.

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* See footnote on page 11-2.

Average gypsum saturation in the scrubber inlet liquor was 75 percent and sulfite oxidation was 15 percent, as opposed to 95 percent saturation and 24 percent oxidation during Run 606-2A. The mist eliminator was 5 percent restricted by scale and solids after 136 operating hours (cf. 10 percent after 122 hours for Run 606-2A) and 8 percent restricted after 212 operating hours at the end of the run. Scaling elsewhere was significantly lighter than for both Runs 604-2A and 606-2A. As expected from the higher magnesium ion concentration, average SO_2 removal improved to 86 percent at 3200 ppm inlet SO_2 concentration compared with 76 percent at 3300 ppm for Run 606-2A. The SO_2 make-per-pass increased correspondingly from about 17.5 m-moles/liter for Run 606-2A to 20 m-moles/liter for Run 607-2A.

11.1.8 TCA Lime/MgO Runs 608-2A and 608-2B

Run 608-2A* was conducted under the same conditions as Run 607-2A, except that solids content in the recirculated slurry was increased from 8 to 15 percent in a continuing effort to obtain scale-free operation at 900 gpm (37 gal/Mcf) slurry flow rate. The mist eliminator was cleaned before Run 608-2A.

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* See footnote on page 11-2.

The scrubber inlet liquor gypsum saturation averaged 95 percent and sulfite oxidation averaged 20 percent during Run 608-2A, compared with 75 percent saturation and 15 percent oxidation during Run 607-2A. Other test results were similar for these two runs. Since there was no scrubber shutdown at the end of Run 608-2A, there was no inspection. However, from the gradual increase of pressure drop across the mist eliminator during Run 608-2A from about 0.49 to 0.54 inch of H_2O, it was possible to infer a buildup of scale and solids.

For Run 608-2B, the effluent hold tank residence time (hence the tank level) was increased from 4.1 to 5.4 minutes with other test conditions unchanged from Run 608-2A. As can be seen in Table 11-1, the test results for these two runs are significantly different as a result of a small change in the residence time. This was quite surprising at the time of these tests, although the reason became quite clear later on.*

Average gypsum saturation in the scrubber inlet liquor dropped drastically from 95 to 11 percent. Sulfite oxidation decreased from 20 to 12 percent. Average scrubber inlet liquor sulfite concentration ($SO_3^=$ and HSO_3^-) increased from 490 to 2780 ppm, with a corresponding increase in the SO_2 removal from 83 percent at 3550 ppm inlet SO_2 concentration to 95 percent at 3100 ppm. The mist eliminator was

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* See footnote on page 11-2.

2 percent restricted by scattered minor scale and solids at the end of Run 608-2B. The pressure drop across the mist eliminator decreased steadily during the run from 0.53 to 0.48 inch of H_2O, indicating a descaling mode of operation. Most of the scale deposits formed during the previous runs had disappeared by the end of Run 608-2B.

11.1.9 TCA Lime/MgO Runs 609-2A through 615-2A

Because of the significant differences in the test results between Run 608-2A (4.1 minutes residence time), and Run 608-2B (5.4 minutes residence time), implying the strong effect of the effluent residence time on sulfite oxidation and gypsum saturation, it was decided at that time to investigate the residence time effect. Runs 609-2A through 615-2A were conducted solely for this purpose.

Unfortunately, it was discovered later that some of the runs made during this lime/MgO test block had air leakage into the scrubber downcomer due to low tank levels (see Footnote on Page 11-2), and the higher sulfite oxidation and gypsum saturation observed for these runs were not a residence time effect. Therefore, it would be inappropriate to discuss the test results of Runs 609-2A through 615-2A since the test objective for these runs was based on the wrong presumption. However, it should be pointed out that, among all lime/MgO runs without downcomer air leakage (see Table 11-1), lower residence times resulted in lower average gypsum saturation (11 to 75 percent average gypsum saturation at 4.1 and 5.4 minutes, compared with 90 to 95 percent at 12 and 16 minutes).

11.2 LIME TESTING WITH FLUE GAS CONTANING FLY ASH

TCA Runs 616-2A and 617-2A were made with flue gas containing fly ash and using lime slurry. These two runs were the only longer term lime tests made on the TA system without the addition of MgO.

11.2.1 TCA Lime Run 616-2A

Typical TCA operating conditions were selected for Run 616-2A (see Table 11-1). Three beds (four grids) were used in the TCA, each bed containing about 5 inches static height of 1-1/2 inch nominal diameter nitrile foam spheres. Fresh lime slurry was added to the scrubber downcomer. Other details of operating conditions can be found in Appendix H.

The objective of Run 616-2A was to observe the TCA performance and reliability with lime scrubbing under typical operating conditions. The scrubber system, including the mist eliminator, was cleaned and the clarifier contents were dumped to purge the system of magnesium ion left over from Run 615-2A.

Average gypsum saturation in the scrubber inlet liquor was 115 percent and sulfite oxidation was 20 percent. Average SO_2 removal was only 72 percent and lime utilization 91 percent at an average inlet SO_2 concentration of 3300 ppm. Solids content in the system discharge sludge averaged 57 percent.

During a scrubber inspection after 133 hours of operation, it was found that the TCA beds had a total static sphere height of only about 11 inches (as a result of shrinkage during previous runs) instead of the desired 15 inches. Additional nitrile foam spheres were added to the beds to a total static bed height of 15 inches, and the operation was continued for another 41 hours. Average SO_2 removal increased to about 82 percent at 3600 ppm inlet SO_2 concentration during this period, with a corresponding increase in the SO_2 make-per-pass from 12 to 15.5 m-moles/liter.

The mist eliminator was essentially clean, with less than 1 percent restricted by solids at the end of the run. Some minor gypsum scale formed on the scrubber walls below the bottom grid.

11.2.2 TCA Lime Run 617-2A

Because Run 616-2A had operated under scaling or near-scaling mode, the solids content in the recirculated slurry was raised from 8 to 15 percent for Run 617-2A to observe if the gypsum scaling potential could be reduced. The mist eliminator was not cleaned prior to Run 617-2A.

Average gypsum saturation in the scrubber inlet liquor was 110 percent and sulfite oxidation averaged 12 percent, compared with 115 percent saturation and 20 percent oxidation for Run 616-2A. Other test results for Runs 616-2A and 617-2A were similar. The mist eliminator condition remained unchanged, with less than 1 percent restricted by solids. Gypsum scale found at the end of Run 616-2A was diminishing by the end of Run 617-2A.

11.3 CONCLUSIONS

Eighteen test runs were made on the TCA system with flue gas containing fly ash and using lime slurry. Sixteen runs were made with MgO addition at 2000 and 4000 ppm effective magnesium ion concentration, and the remaining two runs were made without added MgO. The following conclusions were made from the results of these tests:

- Gypsum scaling occurred at scrubber inlet liquor gypsum saturations as low as 75 percent during runs with MgO addition. Within the range tested, the scrubber inlet liquor pH and percent solids did not have a significant effect on the percent gypsum saturation. Adding fresh lime to the effluent hold tank instead of to the scrubber downcomer (Run 603-2A versus Run 601-2A) resulted in higher gypsum saturation

- Mist eliminator restriction by gypsum scale could occur when the scrubber is operated under gypsum scaling mode with MgO addition, even if the alkali (lime) utilization is high. This does not contradict the earlier finding (Reference 3) that high alkali utilization reduces mist eliminator plugging potential. In the latter case, the restriction of the mist eliminator refers to soft slurry solids

- For runs with MgO addition (and no downcomer air leakage), lower effluent residence times result in lower gypsum saturation. At 4.1 and 5.4 minutes, average gypsum saturation ranged from 11 to 75 percent. At 12 and 16 minutes, the saturation was 90 to 95 percent

- Satisfactory SO_2 removal (about 80 percent) could be achieved with TCA using lime slurry without adding MgO (Runs 616-2A and 617-2A). It appears that 15 percent solids (with fly ash) in the recirculated slurry was required to avoid any gypsum scaling

Section 12

DATABASE

Because of the large amount of data being generated at Shawnee, storage on paper files has become increasingly inappropriate for the data most commonly used in the analysis of the system. In late 1975, conversion to computerized storage within a database was begun. This database is now fully operational.

This form of data storage provides:

- Rapid correction and updating
- Ease of mathematical manipulation
- Ease and accuracy of transmission of the data to the other users
- Permanent, inexpensive, and secure storage
- Ease of presentation of reports and graphs
- Ease of extraction of selected data

The NOMAD database management system operated by National CSS, Inc., was selected for use during this project.

12.1 CONTENTS AND STRUCTURE OF DATABASE

The Shawnee database contains the following information:

- Run data. Included in run data are those items* that have only one value per run, e.g., run number, beginning and ending times, type of alkali added to the system, mist eliminator system configuration, and average analytical data for the run. The run data describe the operating conditions for each individual run

- Solid and liquid analytical data. Most of the data stored in the database consist of results of laboratory analyses performed on solid and liquid samples, usually collected at 8-hour intervals throughout the runs. The stream continually monitored in all runs is the recirculating slurry at the inlet to the scrubber (i.e., the spray tower or the TCA). Analyses are usually performed on calcium, sulfite, and total sulfur concentrations in both solid and liquid phases, magnesium and chloride in the liquid phase, and carbonate in the solid phase. In addition, weight percent of acid insolubles in the solid phase and liquor pH are determined. The database can (1) store these analytical data from any stream and (2) store replicate analytical data from any stream taken at any time during a run

- Gas data. The SO_2 concentrations at the inlet and outlet of each scrubber system are usually recorded hourly. Values at 8-hour intervals are entered into the database

- Flue gas characterization data. These data were collected during a limited number of runs on the venturi/spray tower system (see Section 8) and will be collected on a similar set of TCA runs in early 1977. The data recorded here characterize flue gas mass loading, particulate size distribution, and SO_3 concentration at the inlet and outlet of the scrubber system

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* An item or variable can be either a number or an alphanumeric string encoding a piece of information.

Because the database has a hierarchical structure (see Figure 12-1), it is clear where any piece of information fits into the overall structure. Thus, a record of one analytical result (e.g., a magnesium ion concentration in a liquid phase) is related to its replicate number, the sample point in the system from which the sample was drawn, the time of sampling, the run during which it was sampled, and the system on which the run was performed.

Since the data were not computerized until late 1975, a considerable backlog of data collected prior to that time has to be entered. So far, all venturi/spray tower run and analytical data back to Run 604-1A (starting 04/17/74) and TCA run and analytical data back to Run 533-2A (starting 08/06/74) have been entered. Before the end of the project, all the reliable data collected at Shawnee will be stored in the database. An estimated 200,000 numbers from 2-1/4 years of runs are so far stored in the database.

12.2 SPECIAL FEATURES OF THE DATABASE

Only primary variables (raw data) are stored within the database. Variables derived from these primary variables are not stored in the database (there are several minor exceptions to this) but are defined within the NOMAD database management system (see Table 12-1 for definitions). Such defined variables (e.g., total dissolved solids, SO_2

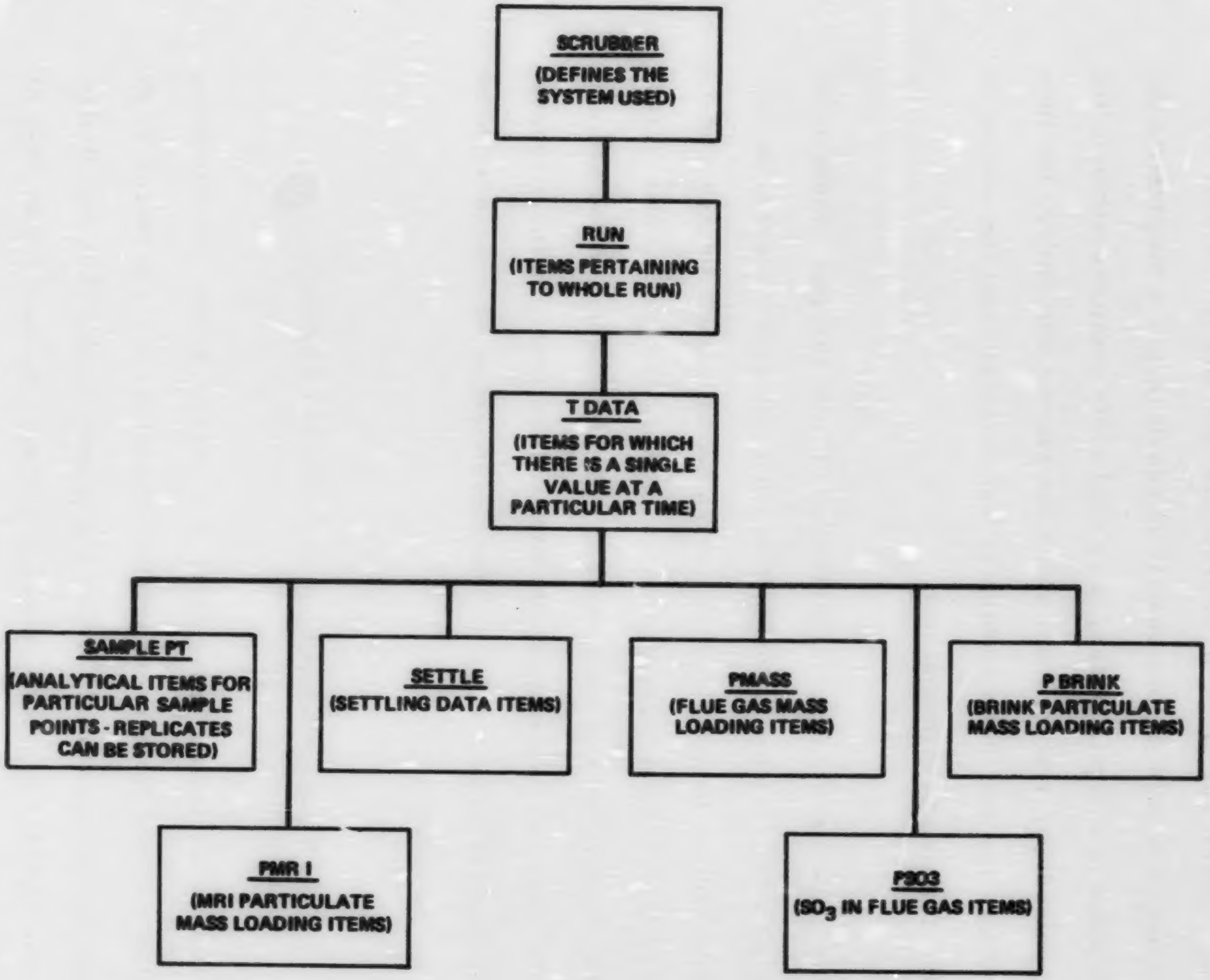
SCRUBBER
(DEFINES THE SYSTEM USED)
RUN
(ITEMS PERTAINING TO WHOLE RUN)
T DATA
(ITEMS FOR WHICH THERE IS A SINGLE VALUE AT A PARTICULAR TIME)
SAMPLE PT
(ANALYTICAL ITEMS FOR PARTICULAR SAMPLE POINTS - REPLICATES CAN BE STORED)
SETTLE
(SETTLING DATA ITEMS)
PMASS
(FLUE GAS MASS LOADING ITEMS)
P BRINK
(BRINK PARTICULATE MASS LOADING ITEMS)
PMR I
(MRI PARTICULATE MASS LOADING ITEMS)
PSO3
(SO3 IN FLUE GAS ITEMS)

Figure 12-1. Hierarchical Structure of the Shawnee Database Showing the Relationships Between the Different Segments

Table 12-1

DERIVED VARIABLES DEFINED IN THE SHAWNEE DATABASE

Defined Variable	Defining Expression Used in Database
SO_2 Removal, %	$100\left(1 - 1.11\,\frac{\text{ppm } SO_2 \text{ out}}{\text{ppm } SO_2 \text{ in}}\right)$
SO_3 Removal, %	$100\left(1 - 1.04\,\frac{\text{ppm outlet } SO_3}{\text{ppm inlet } SO_3}\right)$
Particulate Removal, %	$100\left(1 - 1.04\,\frac{\text{outlet dust, grains/dry scf}}{\text{inlet dust, grains/dry scf}}\right)$
SO_2 Make-per-pass m-moles/liter	$\frac{0.000212\ (\text{gas rate, acfm})\ (\text{ppm } SO_2 \text{ in} - 1.11 \text{ ppm } SO_2 \text{ out})}{\text{total slurry rate to scrubber, gpm}}$
Stoichiometric Ratio	$\frac{\text{wt \% CaO in solids}}{\text{wt \% total S as } SO_3 \text{ in solids}}\left(\frac{80.06}{56.08}\right)$
Stoichiometric Ratio Based on Carbonate	$1 + \frac{\text{wt \% } CO_2 \text{ in solids}}{\text{wt \% total S as } SO_3 \text{ in solids}}\left(\frac{80.06}{44.01}\right)$
Sulfite Oxidation, %	$100\left[1 - \frac{\text{wt \% } SO_2 \text{ in solids}}{\text{wt \% total S as } SO_3 \text{ in solids}}\left(\frac{80.06}{64.06}\right)\right]$
Sulfate in Solids as SO_3, wt%	$\text{wt \% total S as } SO_3 \text{ in solids} - \text{wt \% } SO_2 \text{ in solids}\ \left(\frac{80.06}{64.06}\right)$
Insolubles in Slurry, wt %	$(100 - \text{wt \% CaO} - \text{wt \% } CO_2 - \text{wt \% total S as } SO_3 + 0.25 \text{ wt \% } SO_2)\,\frac{\text{wt \% solids in slurry}}{100}$
Total Dissolved Solids, ppm	$(\text{ppm } Ca^{++} + \text{ppm } Mg^{++} + \text{ppm } Na^{+} + \text{ppm } K^{+} + \text{ppm total S as } SO_4^{=} - 0.020 \text{ ppm } SO_3^{=} + \text{ppm } Cl^{-})$
Sulfate [(a)] Saturation @ 50°C, %	$2.60 \cdot 10^{-8}\ (\text{ppm } Ca^{++})\left[\text{ppm total S as } SO_4^{=} - SO_3^{=}\ \left(\frac{96.06}{80.06}\right)\right]$
	$\left[\frac{263}{\frac{\text{ppm } Ca^{++}}{13360} + \frac{\text{ppm } Mg^{++}}{8103} + \frac{\text{ppm total S as } SO_4^{=}}{96060} - \frac{\text{ppm } SO_3^{=}}{80060}} + 47\right]$
$SO_4^{=}$ Conc., ppm	$\text{ppm total S as } SO_4^{=} - \text{ppm } SO_3^{=}\ \left(\frac{96.06}{80.06}\right)$
Liquid Ionic Imbalance, %	$100\left[1 - \frac{\frac{\text{ppm total S as } SO_4^{=}}{96060} + \frac{\text{ppm } Cl^{-}}{70910}}{\frac{\text{ppm } Ca^{++}}{40080} + \frac{\text{ppm } Mg^{++}}{24310} + \frac{\text{ppm } Na^{+}}{45980} + \frac{\text{ppm } K^{+}}{78200}}\right]$
Solid Ionic Imbalance, %	$100\left[1 - \frac{\frac{\text{wt \% total S as } SO_3 \text{ in solids}}{80.06} + \frac{\text{wt \% } CO_2 \text{ in solids}}{44.01}}{\frac{\text{wt \% CaO in solids}}{56.08}}\right]$

(a) This definition is a modified form of the equation presented in Section 13.

removal, stoichiometric ratio) are calculated each time the database is asked to list them. As a result, such derived variables will always be correctly calculated even if primary variables are changed.

Also stored in the database are three flags that are used to indicate doubtful values in the gas, liquid, and solid data. Codes used for these three items are explained in Appendix D. The flags can be used to limit data selection from the database.

The database does not store all of the data being gathered at Shawnee. For example, alkali addition rate, bleed stream rate, and other system slurry flow rates are not stored there. . The readings of most of the variables (such as inlet and outlet SO_2 concentrations) are taken either continuously or at 1-hour intervals, but only the 8-hour readings are stored in the database. This is done to optimize the cost and usefulness of the system. The database can be enlarged either with more frequent readings of items already present or new items at a future date.

12.3 MAINTENANCE OF THE SHAWNEE DATABASE

The Shawnee data are now being updated daily on weekdays by personnel at the test facility. The data are entered into a computer file on the National CSS, Inc. computer from a terminal located at Shawnee. The file is corrected (edited) and then entered into the database. The data and notes added by the field operation (e.g., comments on daily operation such as down time and scaling problems) are formatted into a daily report. This report is printed out on a San Francisco terminal connected to the same computer for close monitoring of day-to-day operation by Bechtel. (It can also be printed out on any other terminal with access to the computer system.)

12.4 USE OF THE SHAWNEE DATABASE

The simplest use of the database is to produce reports of all or of any selected parts of the database. The reports presented in Appendix D are examples of this capability. These reports are a complete listing of data for the period of this report - February 12, 1976 to December 4, 1976 for the venturi/spray tower system and February 12, 1976 to November 22, 1976 for the TCA system.

The reporting function of the database management system is very powerful: it can search the database for virtually any stored or defined variable; it can format a report easily in accordance with a few simple instructions, and it can define new variables for individual reports. The NOMAD database management system, however, has been limited through the period of this report by its inability to compute logs and powers. This will be rectified by a system modification in late 1977.

Reports of data can be stored in computer files as well as being printed out on paper. Such data can be used for plotting or for mathematical manipulation, such as doing statistical correlations. Examples of the use of such files are presented in the discussion of mathematical modeling in Section 14.

Shawnee data are public information and can be used by any interested party. Use of the database system can be arranged by contacting Bechtel. A user ID will be set up with National CSS, Inc. The user ID provides access to the NCSS timesharing system which includes storage, statistical packages, and several computer languages as well as the Shawnee database. The ID is also used for accounting purposes. User terminals can be located anywhere in the United States; they are connected to the central NCSS computer by telephone.

Section 13

SIMPLIFIED EQUATIONS FOR THE CALCULATION OF GYPSUM SATURATION

Monitoring of gypsum saturation is important because Shawnee testing has demonstrated that scaling usually occurs whenever the saturation exceeds 130 percent at the scrubber outlet. This section presents simplified equations for the calculation of calcium sulfate (gypsum) saturation from the measured concentrations of calcium, magnesium, and sulfate ions. These equations were fitted to the predictions of gypsum saturation made by the Bechtel-Modified Radian Equilibrium Computer Program (Reference 1) for liquors sampled from the Shawnee lime and limestone long-term reliability tests. These equations are used to calculate the gypsum saturation in the Shawnee database.

Equations 13-1 and 13-2 predict the degree of calcium sulfate (gypsum) saturation in lime/limestone wet-scrubbing liquors, at 25 and 50°C, respectively. The equations have been fitted to results from the Bechtel-Modified Radian Equilibrium Computer Program.

At 25°C:

$$\text{Fraction } CaSO_4 \text{ Saturation} = (Ca)\,(SO_4)\left[\frac{300}{I} + 76\right] \qquad (13\text{-}1)$$

At 50°C:

$$\text{Fraction } CaSO_4 \text{ Saturation} = (Ca)\,(SO_4)\left[\frac{263}{I} + 47\right] \qquad (13\text{-}2)$$

where

$$I = 3\,[(Ca) + (Mg)] + (SO_4) \qquad (13\text{-}3)$$

= ionic strength of the liquor (g-mole/l), assuming the liquor contains only Ca^{++}, Mg^{++}, $SO_4^{=}$, and Cl^{-} ions in solution.*

(Ca)
(Mg)
(SO_4) = measured dissolved concentrations of total calcium, magnesium, and sulfate, respectively, g-mole/liter.

Equations 13-1 and 13-2 can be used for simple, accurate, and convenient prediction of sulfate saturation by those not having access to the modified Radian program.

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* From the ionic balance: (Cl) = 2 [(Ca) + (Mg)-(SO_4)]. Therefore, $I = 1/2 \quad \Sigma M_i Z_i^2 = 1/2\,[4\,(Ca) + 4\,(Mg) + 4\,(SO_4) + (Cl)] = 3\,[(Ca) + (Mg)] + SO_4$, where M_i is the molarity of component i and Z_i is its unit charge. Note that K and Na concentrations are low at Shawnee and, therefore, have not been included in Equation 13-3. However, preliminary evaluation of liquor compositions from other limestone and lime installations have indicated that the effect of high dissolved sodium is accounted for by adding the dissolved Na concentration (g-mole/liter) to the ionic strength, I.

To obtain Equations 13-1 and 13-2, 25 run-averaged liquor compositions from the venturi/spray tower and TCA scrubber inlet and outlet were input to the modified Radian program, which calculated the sulfate saturations. The data is presented in Table 13-1. These 25 correlated average compositions were from lime and limestone long-term tests covering the following ranges of variables:

Dissolved calcium concentration (Ca): 8-80 m-mole/liter
Dissolved magnesium concentration (Mg): 2-500 m-mole/liter
Dissolved sulfate concentration (SO_4): 13-400 m-mole/liter
Radian predicted sulfate saturation: 60-225 percent at 25°C
50-190 percent at 50°C

Equation 13-1 accounts for 99.1 percent of the variation in the sulfate saturations of the correlated test points at 25°C, with a standard error of estimate of 0.033 fraction saturation. Equation 13-2 accounts for 99.5 percent of the variation in the saturations at 50°C, with a standard error of 0.020 fraction saturation. See Appendix K for a definition of statistical terms.

Because of concern about the usefulness of Equations 13-1 and 13-2 for liquors containing high concentrations of magnesium ions, chloride ions, or both, the predictions of both the modified Radian program and Equations 13-1 and 13-2 have been compared for 14 Shawnee liquors of this type. These data are presented in Table 13-2.

Table 13-1

DATA USED TO OBTAIN BECHTEL SULFATE SATURATION CORRELATIONS (EQUATIONS 13-1 and 13-2)

Run Number[a]	pH	Measured Total Dissolved Conc., ppm				Calculated Sulfate Saturations			
						@ 25°C		@ 50°C	
		Ca	Mg	SO_4	Cl	by Radian[c]	by Eqn. 13-1[d]	by Radian[c]	by Eqn. 13-2[e]
501-2A	5.85	1800	300	1600	2600	127	125	109	108
502-2A	5.95	1600	200	1250	2200	101	103	87	89
509-2A	5.65	2700	350	1900	4800	162	161	138	138
510-2A	5.45	3000	400	2000	5000	175	170	149	146
514-2A	5.40	3000	350	2000	5000	178	174	151	149
515-2A	5.30	3300	310	2500	5800	225	223	193	191
525-2A	5.80	2100	250	2000	3200	166	165	143	143
526-2A	5.85	2300	340	1900	3700	156	154	133	133
528-2A	5.80	1400	200	1600	1600	121	124	106	107
529-2A	5.80	1900	330	2000	3300	152	153	130	132
530-2A	5.80	1730	340	1900	2790	140	140	120	121
531-2A	5.80	700	5000	15,600	3100	129	124	105	103
531-2A[b]	5.20	800	4800	15,600	3200	150	144	122	120
532-2A	5.80	750	10,500	38,700	2400	187	186	147	148
533-2A	5.85	715	11,800	37,200	3100	161	162	127	128
535-2A	5.95	1800	300	1700	3000	131	132	113	114
603-1A	8.00	2880	190	1670	4770	155	156	134	134
605-1A	9.00	2200	50	1450	3070	138	140	120	121
606-1A	7.90	1350	120	2025	1650	152	161	134	140
608-1A	8.05	2220	320	1920	3900	155	156	133	134
609-1A	8.00	2680	310	1440	4200	129	126	110	109
610-1A	8.10	3100	200	1350	5200	130	129	111	111
610-1A[b]	4.90	2800	280	2300	4300	204	200	175	172
611-1A	7.00	320	3200	11,000	2500	58	58	47	49
611-1A[b]	5.85	600	3200	12,300	2500	116	116	96	98

(a) Compositions in this table are averages for the entire steady-state operating period of each run.
(b) These are scrubber outlet compositions; all others are for scrubber inlet.
(c) Bechtel-Modified Radian Equilibrium Computer Program (Reference 1)
(d) Calculated for 25°C
(e) Calculated for 50°C

Table 13-2

DATA USED TO CHECK BECHTEL SULFATE SATURATION CORRELATIONS (EQUATIONS 13-1 and 13-2)

Run Number	Date and Shift [(a)]	pH	Measured Total Dissolved Conc., ppm					Calculated Sulfate Saturation			
								@ 25° C		@ 50°C	
			Ca	Mg	SO_3	SO_4	Cl	by Radian [(b)]	by Eqn. 13-1 [(c)]	by Radian [(b)]	by Eqn. 13-2 [(d)]
VST-20	2/27N	7.70	4800	490	90	1,000	9,500	99	97	83	82
TCA-113	2/27A	5.70	3450	410	65	1,550	5,500	145	138	122	118
VST-33	3/1A	5.95	5700	580	65	1,400	12,100	140	136	117	115
TCA-34	2/29M	5.70	3800	535	65	1,430	7,160	132	127	110	108
TMG-106	3/22M	5.25	4250	2,300	90	3,070	13,900	194	186	153	157
VMG-105	3/26A	5.85	885	5,900	225	11,700	11,100	114	103	88	90
TMG-151	3/26M	5.45	2400	4,000	970	10,500	10,600	305	295	243	246
TMG-170	3/29A	5.50	960	7,800	1000	14,300	15,100	119	118	89	96
TMG-172	3/30N	7.30	300	12,750	3070	29,800	14,400	52	56	38	44
TMG-173	3/31M	5.50	300	15,200	7900	28,100	13,500	41	46	29	36
TMG-174	3/31N	5.60	480	14,600	3800	36,300	12,800	91	96	69	75
VMG-128	4/8A	5.20	1000	11,100	2700	19,900	14,200	129	133	95	106
TMG-160	4/9A	5.35	960	9,700	1670	22,300	14,400	155	155	118	125
VMG-134	4/15A	5.50	480	12,000	7700	31,200	9,000	85	92	65	73

(a) Shifts: M = morning, A = afternoon, N = night; year = 1976
(b) Bechtel-Modified Radian Equilibrium Computer Program (Reference 1)
(c) Calculated for 25°C
(d) Calculated for 50°C

Note: All liquor samples were taken at the scrubber inlet.

Equation 13-1 explains 99.2 percent of the variation in the Radian sulfate saturation predictions at 25°C, with a standard error of estimate of 0.055 fraction saturation. Equation 13-2 accounts for 98.7 percent of the variation in the 50°C saturations, with a standard error of 0.057 fraction saturation. The only noticeable trend of deviation is that predictions from Equation 13-2 tend to be about 6 to 8 percent high when both dissolved magnesium and chloride ion concentrations are between 8000 and 15,000 ppm.

It is apparent from these results that use of Equations 13-1 and 13-2 gives only minor differences from the predictions of the Radian program. The equations are accurate for total dissolved concentrations of both magnesium and chloride ions up to 15,000 ppm, at least to the extent that the Radian program itself is accurate.

Section 14

MATHEMATICAL MODEL FOR SO_2 REMOVAL

In this section, a semitheoretical model is presented for predicting SO_2 removal by limestone or lime wet-scrubbing as a function of operating variable in a spray tower or a TCA. The model has been fitted to Shawnee data to give predictive equations. Parametric plots and nomographs based on these equations have been developed.

The model is compatible with boundary constraints on SO_2 removal and on the operating variables (e.g., SO_2 removal must be between zero and 100 percent; there is zero removal at zero liquor rate) and should permit reasonable extrapolations beyond the range of fitted data.

The form of the model as developed in Subsection 14.1 should be applicable to similar full scale units. However, the fitted coefficients for Shawnee may differ from those that would best describe another unit because of differences in gas-liquid contacting efficiency.

The present model does not account for possible effects of liquor calcium sulfate (gypsum) saturation or sulfite oxidation on SO_2 removal in the presence of effective magnesium ion. Such effects are relatively insignificant at zero effective magnesium. These effects are discussed in Subsection 14.2.2.

Equations and parametric plots derived from the model are presented in Subsections 14.2 and 14.3 for limestone and lime, respectively. Nomographs are presented in Subsection 14.4.

14.1 DEVELOPMENT OF THE MODEL

Analysis of typical analytical data for limestone and lime wet scrubbing liquors, by the Bechtel-Modified Radian Equilibrium Computer Program (Reference 1), has shown that the equilibrium back-pressure of SO_2 gas is negligible when compared with the actual SO_2 pressure in the bulk gas within the scrubber. For this condition, SO_2 removal is represented by the following equation (see Reference 20):

$$\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\left[\frac{-k_G a\ (z/G)}{1 + k_G a\ (m/k_L a)}\right] \quad (14\text{-}1)$$

where

k_G = gas-side mass transfer coefficient, ft/min

a = gas-liquid interfacial area per scrubber volume, ft^2/ft^3

z = vertical distance in the scrubber, ft

G = volumetric gas rate per cross-sectional area, $acfm/ft^2$

m = Henry's Law constant for SO_2, mole fraction in gas/mole fraction in liquor

k_L = liquid-side mass transfer coefficient, including both physical and chemical absorption, ft/min

A comparison of Shawnee SO_2 removal data for limestone/lime scrubbing with Shawnee data for gas-side-controlled soda-ash scrubbing has shown that liquid-side resistance is predominant (i.e., $k_L/m \ll k_G$) for nearly all of the limestone/lime data (see Reference 1). For this condition, Equation 14.1 can be simplified to:

$$\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\left[\frac{-k_L a z}{mG}\right] \qquad (14\text{-}2)$$

The liquid-side coefficient for absorption with chemical reaction can be divided into two parameters, one for physical absorption and the other for chemical reaction, by writing (as is done in Reference 20):

$$k_L = \bar{\phi}\, k_L^{o} \qquad (14\text{-}3)$$

where:

k_L^o = liquid film mass transfer coefficient for physical absorption, ft/min

$\bar{\phi}$ = average chemical reaction enhancement factor for mass transfer in the liquid film, dimensionless

Equation 14-2 becomes:

$$\text{Fraction } SO_2 \text{ Removal} = 1 - \exp \bar{\phi} \left[\frac{-k_L^o az}{mG} \right] \qquad (14\text{-}4)$$

The parameters in the group ($k_L^o az/mG$) are functions of liquor rate, gas rate, and scrubber internals (e.g., number of grids and total height of spheres in the TCA). For limestone and lime wet scrubbing at Shawnee, the group ($k_L^o az/mG$) has been successfully represented by the following equation (see Reference 1):

$$k_L^o a z/mG = \alpha_1 \; (L/G)^{\alpha_2} v^{\alpha_3} \left[1 + \alpha_4 \left(\frac{h_{tot}}{d_s} + N_G \right) \right] \qquad (14\text{-}5)$$

where:

L/G = liquid-to-gas ratio in the scrubber, gal/Mcf

v = gas velocity in the scrubber, ft/sec

h_{tot} = total height of the spheres in the TCA, inches (zero for the spray tower)

d_s = diameter of TCA spheres, 1.5 inches at Shawnee

N_G = number of grids or screens in the TCA, normally four at Shawnee (zero for spray tower)

α's = constant coefficients to be fitted to limestone/lime wet-scrubbing data

The bracketed term in Equation 14-5 is equal to one for spray tower calculations.

The enhancement factor, $\bar{\phi}$, is a representation of the chemical reactivity of the scrubber liquor with absorbed SO_2 gas. This reactivity may be expressed in terms of such variables as the scrubber inlet gas SO_2 concentration, scrubber inlet liquor pH, and the total concentrations of the dissolved chemical species, e.g., magnesium and chloride. An empirical relationship for $\bar{\phi}$ that is compatible with boundary constraints is:

$$\bar{\phi} = \exp\left[\alpha_5 pH_i + \alpha_6 (Mg)_e - \alpha_7 (SO_2)_i\right] \qquad (14\text{-}6)$$

where:

pH_i = scrubber inlet liquor pH

$(Mg)_e$ = effective magnesium ion concentration, ppm

= [ppm Mg^{++} - (ppm $Cl^-/2.92$)] for $Mg^{++} > Cl^-/2.92$

= 0 for $Mg^{++} < Cl^-/2.92$

where 2.92 = ratio by weight of Cl^- to Mg^{++} in $MgCl_2$

$(SO)_i$ = scrubber inlet gas SO_2 concentration, ppm

α's = constants to be fitted to data

Other variables that can affect liquor reactivity, such as sodium ion concentration, sulfate saturation, and sulfite oxidation, have not been included in Equation 14-6 because no effect on SO_2 removal attributable to these variables was observed within the range of operating conditions for most of the Shawnee limestone and lime test runs.

The use of effective, rather than total, dissolved magnesium in Equation 14-5 reflects the fact that chloride neutralizes magnesium to produce dissolved $MgCl_2$, which is not useful for removing SO_2 (see Section 5.3).

Combining Equations 14-5 and 14-6 with 14-4 to calculate SO_2 removal yields:

$$\begin{aligned}\text{Fraction } SO_2 \text{ Removal} &= 1 - \exp\left\{ -\alpha_1 (L/G)^{\alpha_2} (v)^{\alpha_3} \left[1 + \alpha_4 \left(\frac{h_{tot}}{d_s} + N_G\right)\right]\right. \\ &\left. \exp\left[\alpha_5 \, pH_i + \alpha_6 \, (Mg)_e - \alpha_7 \, (SO_2)_i\right]\right\} \qquad (14\text{-}7)\end{aligned}$$

Equation 14-7 is a preliminary equation for correlating SO_2 removal by limestone or lime with operating variables. In the actual fitting of the Shawnee TCA data, the following modification of Equation 14-5, and hence of Equation 14-7, was found to be more useful for TCA correlations:

$$k_L^o a z/mG = \alpha_1 (L/G)^{\alpha_2} v^{\alpha_3} \exp\left[\alpha_4 v \left(\frac{h_{tot}}{d_s} + N_G\right)\right] \qquad (14\text{-}8)$$

Equation 14-8 includes the interaction effect of gas velocity v with a scrubber internals term, which is expressed as ($h_{tot}/d_s + N_G$). This interaction effect was found to be statistically significant in the most recent (February through April 1976) Shawnee TCA limestone factorial runs and lime factorial runs. This significance can be explained in terms of superior sphere agitation and increased liquid-gas contacting at higher gas velocities.

Another correction to Equation 14-7 is required because of the presence of chloride ion in the scrubbing liquor. When the chloride ion concentration increases, the pH in the effluent hold tank tends to decrease (see Section 5.3.2) To maintain the pH in the tank, the stoichiometric ratio must be increased. This increased stoichiometric ratio increases the SO_2 removal. Therefore, the effect of scrubber inlet liquor pH on SO_2 removal, as expressed in Equation 14-7, was corrected for chloride ion concentration of the scrubber inlet liquor as follows:

$$(pH_i)_{corr} = pH_i + \alpha_8 \, Cl \qquad (14\text{-}9)$$

where

$(pH_i)_{corr}$ = effective value of scrubber inlet liquor pH (when related to actual limestone stoichiometry), corrected for dissolved chloride concentration

Cl = chloride ion concentration, ppm

Thus the enhancement effect of increased stoichiometry on SO_2 removal is represented in the model by $(pH_i)_{corr}$.

The use of Equations 14-8 and 14-9 to modify Equation 14-7 gives the final form to the semitheoretical equation. This form was fitted individually to the Shawnee TCA and spray tower limestone and lime wet-scrubbing data sets:

$$\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\left\{ - \alpha_1 (L/G)^{\alpha_2} v^{\alpha_3} \exp\left[\alpha_4 v \left(\frac{h_{tot}}{d_s} + N_G \right) + \alpha_5 \, pH_i + \alpha_6 (Mg)_e - \alpha_7 (SO_2)_i + \alpha_8 Cl \right] \right\} \qquad (14\text{-}10)$$

where

Cl = measured total dissolved chloride ion concentration, ppm

d_s = diameter of the TCA sphere (1.5 inches at Shawnee)

h_{tot} = total height of the spheres in the TCA, inches

L/G = liquid-to-gas ratio in the scrubber (125 °F, humidified gas), gal/Mcf

$(Mg)_e$ = effective magnesium ion concentration, ppm
= $[\text{ppm } Mg^{++} - (\text{ppm } Cl^-/2.92)]$ for $Mg^{++} > Cl^-/2.92$
= 0 for $Mg^{++} \leq Cl^-/2.92$
where 2.92 = ratio by weight of Cl^- to Mg^{++} in $MgCl_2$

N_G = number of grids or screens in the TCA (four at Shawnee)

pH_i = scrubber inlet liquor pH

$(SO_2)_i$ = inlet gas SO_2 concentration, ppm

v = gas velocity in the scrubber (125° F, humidified gas), ft/sec

$\alpha_1 \ldots \alpha_8$ = constant coefficients to be fitted to the data for SO_2 removal by limestone/lime wet-scrubbing

and where $[h_{tot}/d_s + N_G]$ equals zero for the spray tower

The correlations obtained using Equation 14-10 are presented in Subsections 14.2 and 14.3.

14.2 FITTED EQUATIONS FOR SO2 REMOVAL BY LIMESTONE SLURRY

In this subsection, two equations for SO_2 removal by limestone slurry are presented - one for the spray tower and one for the TCA - and parametric plots based on these equations are shown. These equations, which have the form of Equation 14-10, were fitted to run-averaged Shawnee factorial and long-term limestone data.

Nomographs are presented in Subsection 14.4.

Because of the narrow range of inlet SO_2 concentration during the factorial tests, additional data from other sources were used to estimate the effect of inlet gas SO_2 concentration on SO_2 removal.

14.2.1 Estimation of Effect of Inlet SO_2 Concentration

The run-averaged measurements of inlet SO_2 concentration during Shawnee limestone factorial testing did not vary enough to determine a statistically significant effect of inlet SO_2 on SO_2 removal. Therefore, this effect was estimated from: individual data recorded at specific times throughout Shawnee TCA long-term limestone Runs 535-2A and 535-2B, during which inlet SO_2 concentration ranged from 1500 to 4900 ppm; data from the 300 cfm TCA pilot scrubber operated by the EPA at Research Triangle Park, N. C. (Reference 21); and data from an 8 cfm TVA pilot spray tower (Reference 22).

The EPA pilot scrubber is a 9-inch-diameter, three-stage TCA (cross-sectional area of 0.44 ft^2). Data were taken at a slurry flow rate of 17 gpm, a gas velocity of 7.5 ft/sec (190 ft^3/min), a liquid-to-gas ratio of 86 $\pm$ 3 gal/Mcf at 125°F, 16 weight percent solids recirculated, and 7 inches of 3/4-inch-diameter spheres per bed.

The TVA pilot scrubber is a 4-inch I.D. glass tube spray tower with two nozzles. Data were taken at a liquid-to-gas ratio of 80 gal/Mcf at an average inlet gas temperature of 175°F, corresponding to 87 gal/Mcf at 125°F. The solids concentration in the recirculating slurry was 2 weight percent.

The detailed operating conditions for Shawnee TCA limestone Runs 535-2A and 535-2B are given in Appendix F, Reference 2. The gas velocity was 8 ft/sec and the recirculating slurry flow rate was 1200 gpm (i.e., a liquid-to-gas ratio of 50 gal/Mcf). Three beds of hollow thermoplastic rubber (TPR) spheres (1-1/2 inch diameter, 5 inches height per bed) were used; the solids concentration in the recirculating slurry was 13 weight percent.

The following equation for SO_2 removal as a function of inlet gas SO_2 concentration has been fitted to the seven data points obtained from the EPA and TVA pilot scrubbers:

$$\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\left\{- 2.8 \exp\left[-1.73 \times 10^{-4} (SO_2)_i\right]\right\} \tag{14-11}$$

Figure 14-1 sompares the seven experimental data points from the EPA and TVA tests with a curve representing Equation 14-11. The

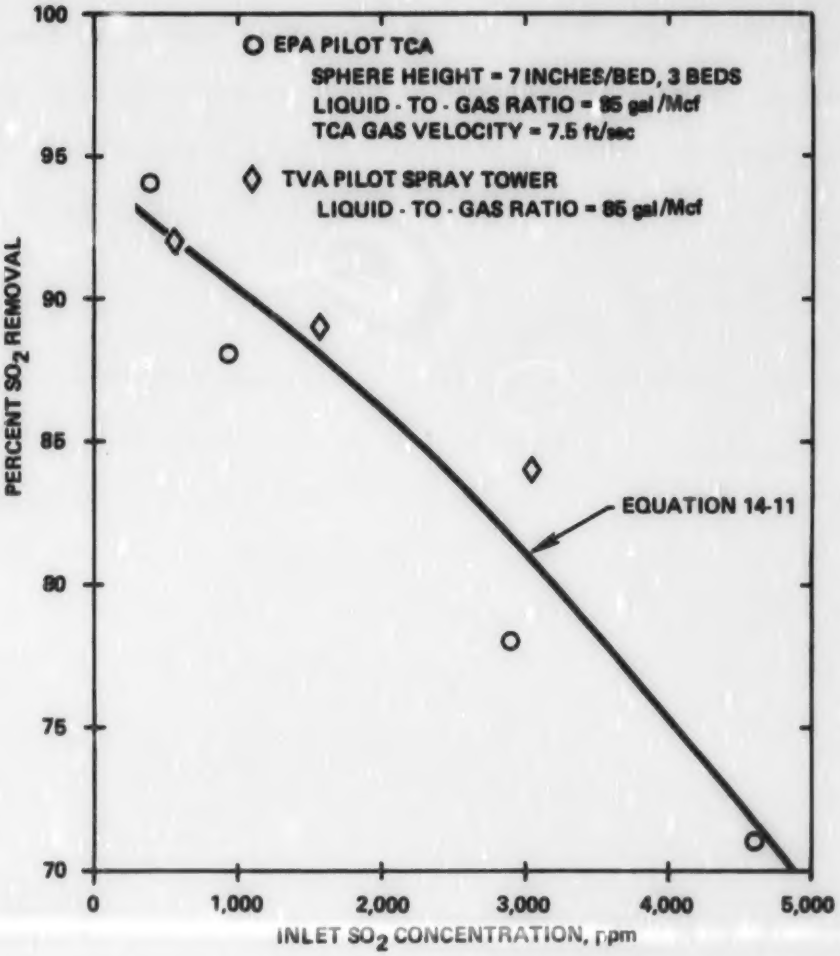

Figure 14-1. Effect of Inlet SO_2 Concentration on SO_2 Removal

equation accounts for 91 percent of the variation in the data, with a standard error of estimate of 2.7 percent SO_2 removal.

Equation 14-12 below has been fitted to 213 individual data points obtained from Shawnee TCA Runs 535-2A and 535-2B:

$$\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\left\{ - 0.174 \exp\left[0.47\, pH_i - 1.6 \times 10^{-4} (SO_2)_i \right]\right\} \qquad (14\text{-}12)$$

Equation 14-12 accounts for 69 percent of the variation in the data, with a standard error of estimate of 2.2 percent SO_2 removal.

A comparison of Equations 14-11 and 14-12 shows that the coefficients of inlet SO_2 concentration are nearly the same at about 1.7×10^{-4}. Although most of the data to which Equations 14-11 and 14-12 were fitted were from TCA scrubbers, Shawnee results with the TCA and the spray tower indicate that the effects of operating variables on SO_2 removal by limestone are similar for both scrubber types (see Subsections 14.2.3 and 14.2.4). Therefore, in Equation 14-10 the coefficient of the inlet SO_2 term, a_7, has been set at 1.7×10^{-4}.

Figure 14-2 is a plot showing the effect of inlet SO_2 concentration on percent SO_2 removal, as determined in this subsection. It was derived

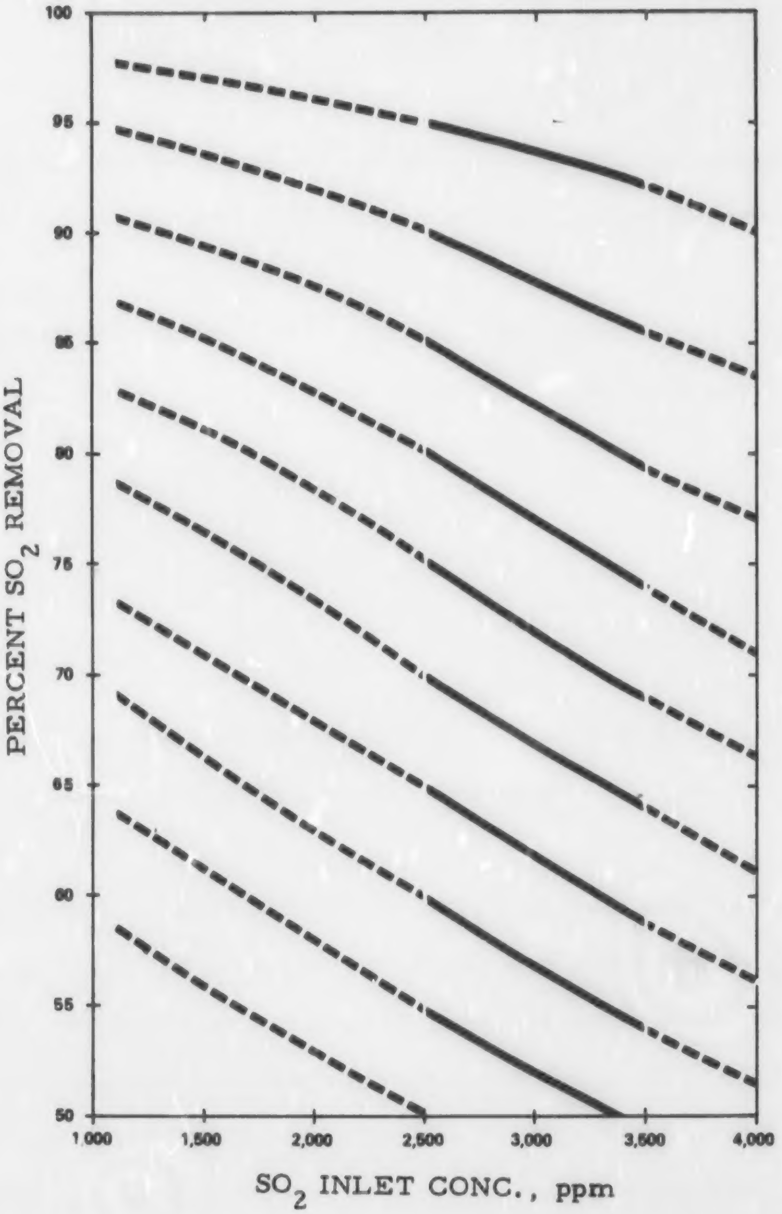

Figure 14-2 can be used to predict the effect of a change in SO_2 inlet concentration on SO_2 removal. When the SO_2 removal, $(SO_2R)_1$, at a particular inlet SO_2 concentration, $(SO_2i)_1$, is known, the removal, $(SO_2R)_2$, at a different inlet SO_2 concentration, $(SO_2i)_2$, is obtained by first locating the point $[(SO_2i)_1, (SO_2R)_1]$ and then paralleling the nearest curve until $(SO_2i)_2$ is reached. The corresponding value on the y axis is then $(SO_2R)_2$.

Figure 14-2. Predicted Effect of Inlet SO_2 Concentration on SO_2 Removal from Equation 14-13.

from a series of equations of the form:

$$\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\left\{-C_1 \exp\left[-1.7 \times 10^{-4} (SO_2)_i\right]\right\} \quad (14\text{-}13)$$

where

C_1 is a constant set by operating conditions

Figure 14-2 can be used to predict the effect of a change in inlet SO_2 concentration on SO_2 removal. When the SO_2 removal, $(SO_2R)_1$, at a particular inlet SO_2 concentration, $(SO_2i)_1$, is known, the removal, $(SO_2R)_2$, at a different inlet SO_2 concentration, $(SO_2i)_2$, is obtained by first locating the point $[(SO_2i)_1, (SO_2R)_1]$ in Figure 12-2, and then paralleling the nearest curve until $(SO_2i)_2$ is reached. The corresponding value on the vertical axis is then $(SO_2R)_2$.

The solid lines in Figure 14-2 cover the range of average inlet SO_2 concentrations usually obtained at Shawnee for limestone runs, approximately 2500 to 3500 ppm. The dashed lines cover essentially the entire range of inlet SO_2 concentrations that was fitted by Equations 14-11 and 14-12 (400 to 4600 ppm).

14.2.2 Qualitative Effects of Gypsum Saturation and Sulfite Oxidation in the Presence of Effective Magnesium Ion

For limestone/lime wet-scrubbing, the presence of effective magnesium ion increases the reactivity of the scrubber liquor with SO_2, thus increasing SO_2 removal. The magnitude of this effect can depend on either calcium sulfate (gypsum) saturation or sulfite oxidation. The effects of gypsum saturation and sulfite oxidation on SO_2 removal are not accounted for by Equation 14-10 and are discussed below.

The increased reactivity of liquor containing effective magnesium ion occurs because increased magnesium increases the concentration of dissolved sulfite (not bisulfite) species, e.g., $SO_3^=$ ion and the magnesium sulfite ($MgSO_3^o$) ion pair.* These sulfite species can react with incoming SO_2, thus enhancing SO_2 removal.

These effects of increased magnesium ion on the sulfite species are predicted by the Bechtel-Modified Radian Equilibrium Computer Program and have been verified by liquor analytical data obtained at Shawnee.

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* The increase in sulfite ($SO_3^=$) concentration is required to satisfy the ionic balance when Mg^{++} ion is added to the liquor. The $MgSO_3^o$ concentration also increases, because of the equilibrium among Mg^{++}, $SO_3^=$, and $MgSO_3^o$. Naturally, other negative ions such as bisulfite (HSO_3^-) and sulfate ($SO_4^=$) also increase with increasing Mg^{++}, but these other negative ions do not react with SO_2.

At high magnesium ion concentrations, a decrease in gypsum saturation can increase the concentration of the reactive sulfite species, thus adding to the normal magnesium ion enhancement effect on SO_2 removal. The effect of low gypsum saturation on the concentration of dissolved sulfite species is explained as follows:

- By definition, a decrease in gypsum saturation means that the product of calcium ion activity and sulfate ion activity is reduced. When this occurs, the concentrations of calcium ion and/or sulfate ion are reduced
- The reduction in calcium ion allows the concentration of sulfite ion to increase in accordance with the solubility product for calcium sulfite. A reduction in sulfate ion also increases the concentration of sulfite ion in order to preserve the ionic balance
- The increase in sulfite ion also increases the concentration of the $MgSO_3^o$ ion pair in order to maintain chemical equilibrium of $MgSO_3^o$ with sulfite and magnesium ions

Very high sulfite oxidation (near 100 percent) results in low sulfite specie concentration, and hence in lower SO_2 removal. At such high oxidation, the beneficial effect of magnesium on SO_2 removal should be reduced below the prediction of Equation 14-10.

These potential effects of sulfate saturation and sulfite oxidation on SO_2 removal have not been included in Equation 14-10 because operating conditions for most of the Shawnee limestone/lime test runs have not been in the appropriate range to observe the effects. However, a few recent lime/MgO tests at Shawnee, e.g., Runs 643-1A (10% saturation) and 608-2B (11% saturation), have verified that higher SO_2 removals can be obtained for subsaturated operation. Therefore, caution should be exercised in applying the correlations discussed in Subsections 14.2 and 14.3 to high-magnesium limestone/lime wet-scrubbing.

14.2.3 Spray Tower Equation for SO_2 Removal by Limestone Slurry

The following equation for SO_2 removal (having the form of Equation 14-10) has been fitted to the 61 spray tower limestone and limestone/MgO factorial runs made during 1976 (see Section 6) and to 16 venturi/spray tower long-term limestone runs (Runs 701-1A through 717-1A)*:

$$\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\left\{- 9.8 \times 10^{-5} (L/G)^{0.92} v^{0.19} \exp\left[pH_i + 1.35 \times 10^{-4} (Mg)_e - 1.7 \times 10^{-4} (SO_2)_i + 1.45 \times 10^{-5} Cl \right]\right\} \quad (14\text{-}14)$$

where:

Cl = measured total dissolved chloride concentration, ppm

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* Two spray tower factorial runs (Runs VMG-150 and VMG-151) with only a single operating spray header were excluded from the correlation.

L/G = liquid-to-gas ratio in the scrubber (125°F, humidified gas), gal/Mcf

$(Mg)_e$ = effective magnesium-ion concentration, ppm
$= [\text{ppm } Mg^{++} - (\text{ppm } Cl^- /2.92)]$ for $Mg^{++} > Cl^- /2.92$
$= 0$ for $Mg^{++} \leq Cl^- /2.92$
where 2.92 = ratio by weight of Cl^- to Mg^{++} in $MgCl_2$

pH_i = scrubber inlet liquor pH

$(SO_2)_i$ = inlet gas SO_2 concentration, ppm

v = gas velocity in the scrubber (125°F, humidified gas), ft/sec

The run-averaged values of the variables used in Equation (14-14) are tabulated in Table 14-1.

The fitted ranges of the operating variables in Equation 14-14 are given below. Equation 14-14 should not be extrapolated beyond these ranges.

L/G	25-95 gal/Mcf
v	5.3-9.3 ft/sec
pH_i	5.2-6.0
$(Mg)_e$	0-10,000 ppm
$(SO_2)_i$	1500-4500 ppm
Cl	3000-17,000 ppm

For the venturi/spray tower long-term runs, the SO_2 removal in the spray tower only was estimated by correcting for the expected SO_2 removal in the venturi as predicted from venturi factorial tests. For the spray tower factorial runs, the venturi with wide-open throat and minimum slurry flow rate (about 150 gpm) gave very low SO_2 removal (about 5 percent). For such a low venturi removal, the spray tower

Table 14-1

RUN-AVERAGED SPRAY TOWER RESULTS FOR LIMESTONE SCRUBBING TO WHICH EQUATION 14-14 WAS FITTED

Run Number	Gas Velocity, fps	L/G, gal/Mcf	Inlet pH	Effective Magnesium, ppm	Chloride Ion Conc., ppm	Inlet SO_2 Conc., ppm	SO_2 Removal, %
VMG-102	7.3	68.2	5.56	503	13700	2387	84
VMG-103	7.3	68.2	5.22	422	14732	2400	70
VMG-104	7.3	51.1	5.77	0	14800	2352	80
VMG-105	7.3	51.1	5.53	1256	12000	2373	69
VMG-106	7.3	51.1	5.24	537	11950	2457	59
VMG-107	7.3	51.1	5.79	1156	12800	2432	80
VMG-108	7.3	34.1	5.51	1422	13000	2648	52
VMG-109	7.3	34.1	5.20	815	13500	2697	42
VMG-117	7.3	68.2	5.53	3810	14057	2552	95
VMG-118	7.3	68.2	5.20	4477	12996	2783	85
VMG-119	7.3	68.2	5.53	5054	14377	2448	93
VMG-120	7.3	51.1	5.49	4209	15500	2508	79
VMG-121	9.3	40.2	5.53	4119	17000	2507	76
VMG-122	5.3	70.3	5.51	3707	16685	2417	86
VMG-123	7.3	51.1	5.23	3499	15265	2520	68
VMG-124	7.3	51.1	5.79	3795	15087	2460	87
VMG-125	7.3	51.1	5.51	4028	16330	2593	78
VMG-126	9.3	40.2	5.51	3179	15880	2368	73
VMG-127	7.3	34.1	5.49	4293	14318	2964	67
VMG-128	7.3	34.1	5.19	5614	14067	3300	60
VMG-129	7.3	34.1	5.52	4710	14676	2428	71
VMG-130	7.3	68.2	5.57	8697	9833	3528	98
VMG-131	7.3	68.2	5.23	9234	9585	3750	95
VMG-132	7.3	51.1	5.25	10383	9407	3263	91
VMG-133	7.3	51.1	5.81	8043	8890	3270	96
VMG-134	7.3	51.1	5.50	9307	8410	3440	97
VMG-135	7.3	51.1	5.18	9198	8727	2370	88
VMG-136	7.3	34.1	5.25	8635	8342	2535	85
VMG-137	7.3	34.1	5.54	9920	6981	2693	92
VMG-144	7.3	34.1	5.54	4221	15380	2640	74
VMG-145	9.3	26.8	5.48	8669	7839	2713	81
VMG-146	9.3	40.2	5.45	9633	9407	3663	94
VMG-147	7.3	34.1	5.42	9106	8497	3075	83
VMG-148	7.3	51.1	5.53	8248	9082	2440	96
VST-116	9.3	40.2	5.84	0	15300	2543	72
VST-117	9.3	26.8	5.80	0	12900	2773	58
VST-118	5.3	93.7	5.75	0	13600	3164	88
VST-119	7.3	51.1	5.83	0	15750	2569	76
VST-120	5.3	70.3	5.79	0	14300	2626	79
VST-121	9.3	26.8	5.81	0	12950	2629	59
VST-122	7.3	68.2	5.81	0	13800	2928	80
VST-123	9.3	53.6	5.80	0	13100	3122	74
VST-124	7.3	51.1	5.83	0	14800	2554	78
VST-125	5.3	46.9	5.78	0	12900	2771	68
VST-126	5.3	93.7	5.83	0	14700	2900	90
VST-127	7.3	34.1	5.82	0	12900	2633	65
VST-128	7.3	51.1	5.54	0	12900	2530	67
VST-129	7.3	68.2	5.51	0	15500	2947	73
VST-130	7.3	68.2	5.16	0	16100	2823	66
VST-131	7.3	51.1	5.17	0	16200	2648	56
VST-132	7.3	68.2	5.21	0	15350	2537	67
VST-134	7.3	34.1	5.78	0	12900	2717	60
VST-136	7.3	34.1	6.02	0	14300	3020	69
VST-137	7.3	34.1	5.81	0	13500	2580	63
VST-138	7.3	51.1	5.68	0	14000	3065	66
VST-139	7.3	51.1	5.78	0	13600	2535	73
VST-140	7.3	51.1	5.75	0	14500	2738	68

Table 14-1 (continued)

RUN-AVERAGED SPRAY TOWER RESULTS FOR LIMESTONE SCRUBBING TO WHICH EQUATION 14-14 WAS FITTED

Run Number	Gas Velocity, fps	L/G, gal/Mcf	Inlet pH	Effective Magnesium, ppm	Chloride Ion Conc., ppm	Inlet SO_2 Conc., ppm(1)	SO_2 Removal, %(1)
VST-141	7.3	35.5	5.99	0	13250	2610	72
VST-142	7.3	34.1	5.20	0	13000	2683	43
VST-143	7.3	34.1	5.50	0	13000	2480	52
VST-144	7.3	34.1	5.89	0	13000	2673	70
701-1A	9.3	57.1	5.90	0	4920	1584	79
702-1A	9.3	50.0	5.80	0	4780	1991	71
703-1A	9.3	50.0	5.20	0	6210	2171	43
704-1A	9.3	50.0	5.80	0	6200	1991	76
705-1A	9.3	53.6	5.80	0	4020	1962	73
706-1A	9.3	50.0	5.25	0	3830	2200	41
707-1A	9.3	50.0	5.70	0	4410	2106	71
708-1A	9.3	50.0	5.65	0	4560	2117	58
709-1A	9.3	50.0	5.80	0	3660	2109	66
710-1A	9.3	50.0	6.00	0	3400	1740	78
711-1A	9.3	50.0	5.70	0	3740	1984	67
711-1B	9.3	50.0	5.70	0	4930	1831	71
712-1A	9.3	50.0	5.85	0	4940	1892	79
713-1A	9.3	50.0	5.28	0	5570	2071	65
714-1A	9.3	50.0	5.55	3192	5280	1967	86
717-1A	9.3	50.0	5.45	3508	4180	2135	82

(1) For long-term Runs 701-1A to 717-1A, overall inlet SO_2 concentrations and SO_2 removals were corrected for venturi SO_2 removal to give the estimated spray tower inlet SO_2 concentrations and SO_2 removals used in Equation 14-14.

removal differs from the total system removal by only one percentage point or less. Therefore, no correction for venturi removal was made for these runs.

In Equation 14-14, the coefficient of the inlet gas SO_2 concentration term, -1.7×10^{-4}, was obtained from individual Shawnee long-term data points and from EPA and TVA pilot scrubber data (see Subsection 14.2.1).

A decrease of about 5 percent in the SO_2 removal was observed for two runs (Runs VST-138 and VST-140) made at a spray nozzle pressure drop of 8 psig, reduced from the normal 12 to 13 psig. However, there were not enough data to permit accurate correlation of the nozzle pressure drop effect.

Measured percent SO_2 removals and those predicted from Equation 14-14 are shown in Figure 14-3. Equation 14-14 accounts for 92 percent of the variation in the combined data (94 percent for the factorial data and 80 percent for the long-term data) with a standard error of estimate of 3.9 percent SO_2 removal (3.3 percent for the factorial data and 5.7 percent for the long-term data).

Figures 14-4 through 14-10 are parametric plots derived from Equation 14-14, showing predicted SO_2 removals and the corresponding Shawnee spray tower limestone data. Equation 14-14 was fitted to all available

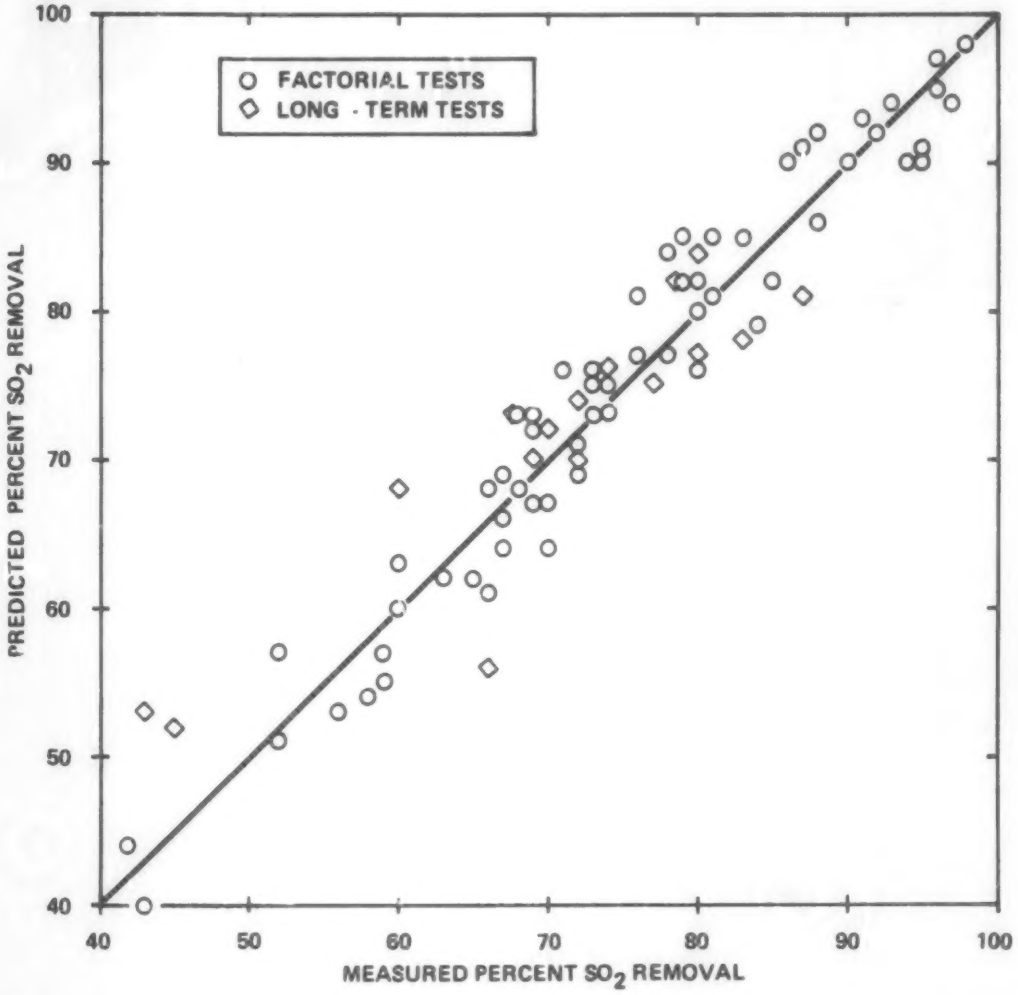


Figure 14-3. Comparison of Experimental Data and Predicted Values (Equation 14-14) of SO_2 Removal - Spray Tower with Limestone

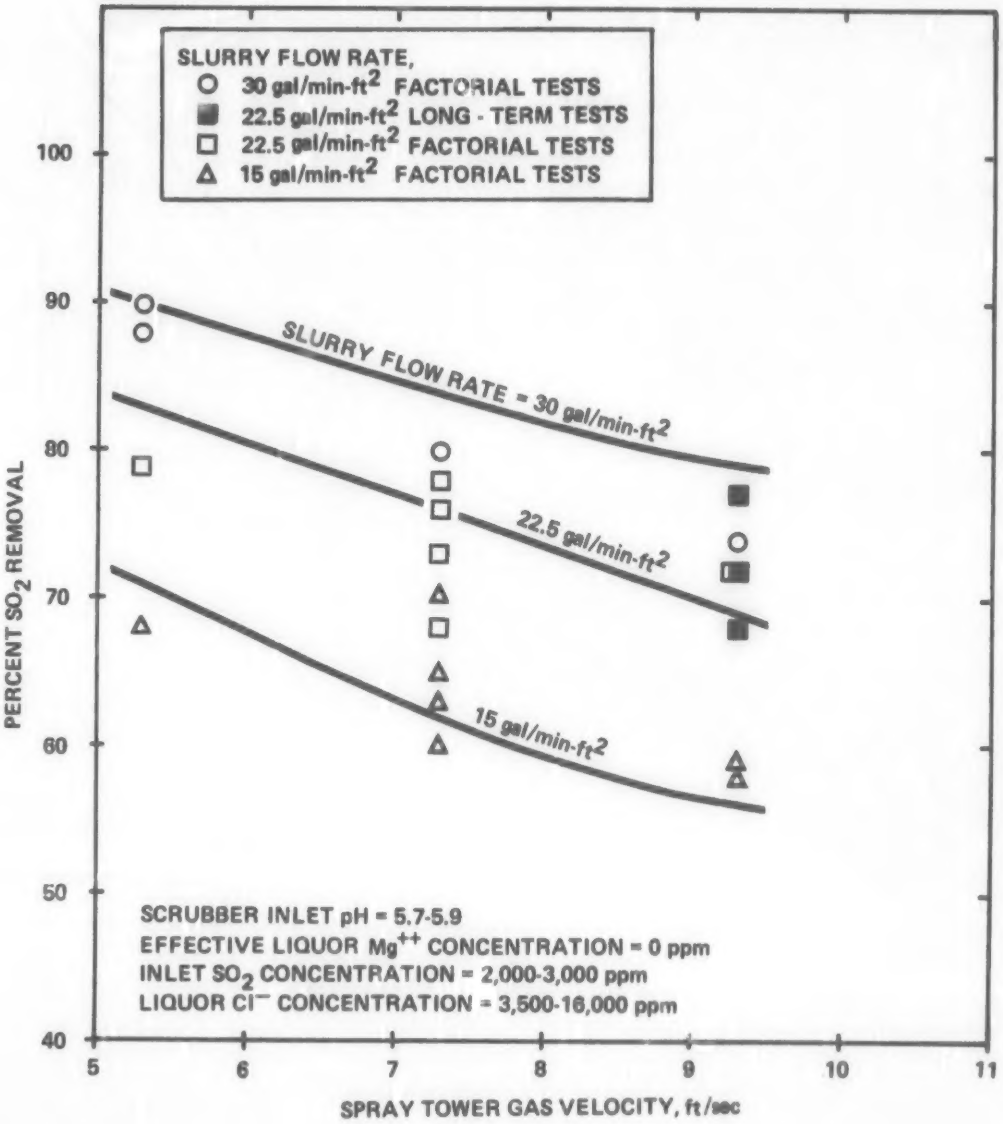


Figure 14-4. Gas Velocity and Slurry Flow Rate Versus Predicted (Equation 14-14) and Measured SO_2 Removal - Spray Tower with Limestone

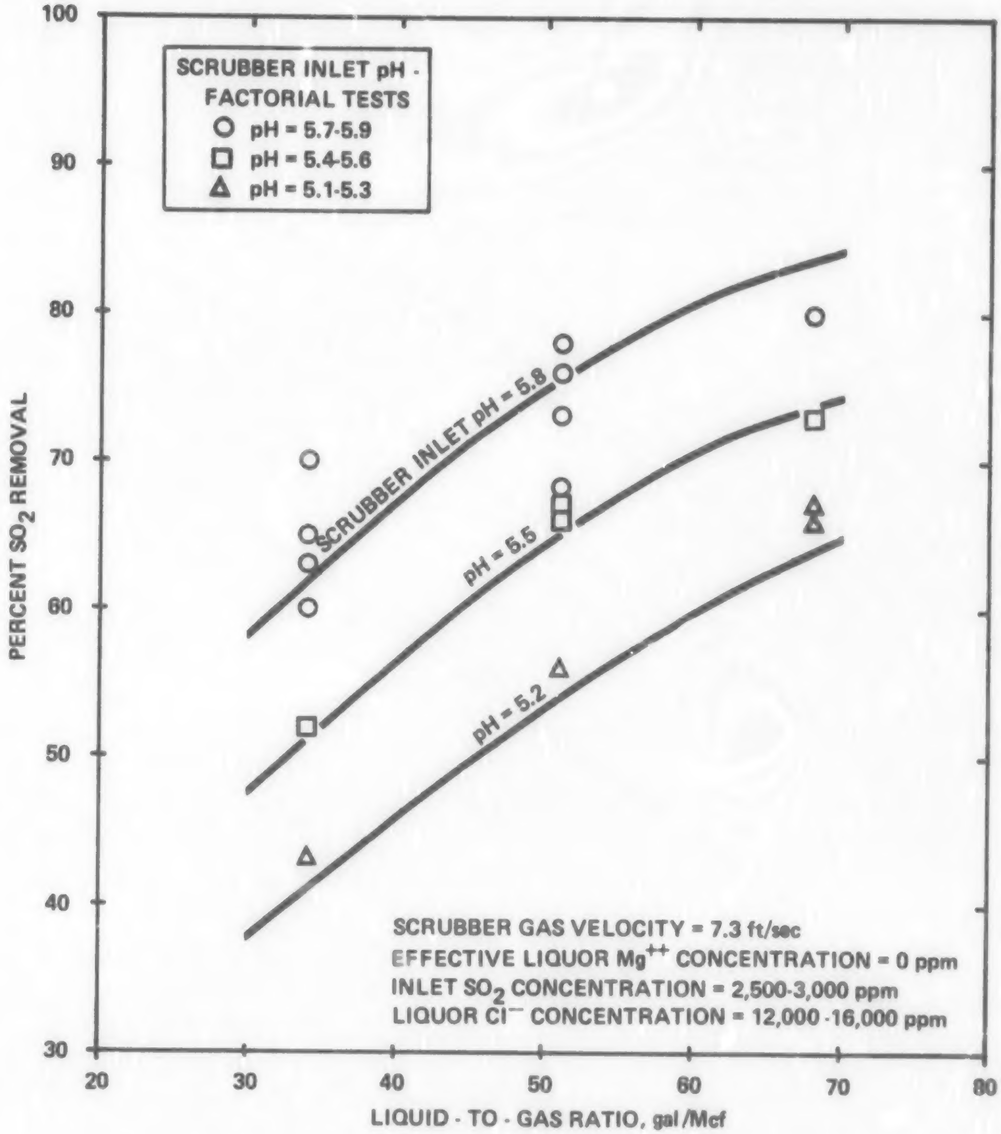


Figure 14-5. Liquid-to-Gas Ratio and Scrubber Inlet pH Versus Predicted (Equation 14-14) and Measured SO_2 Removal - Spray Tower with Limestone

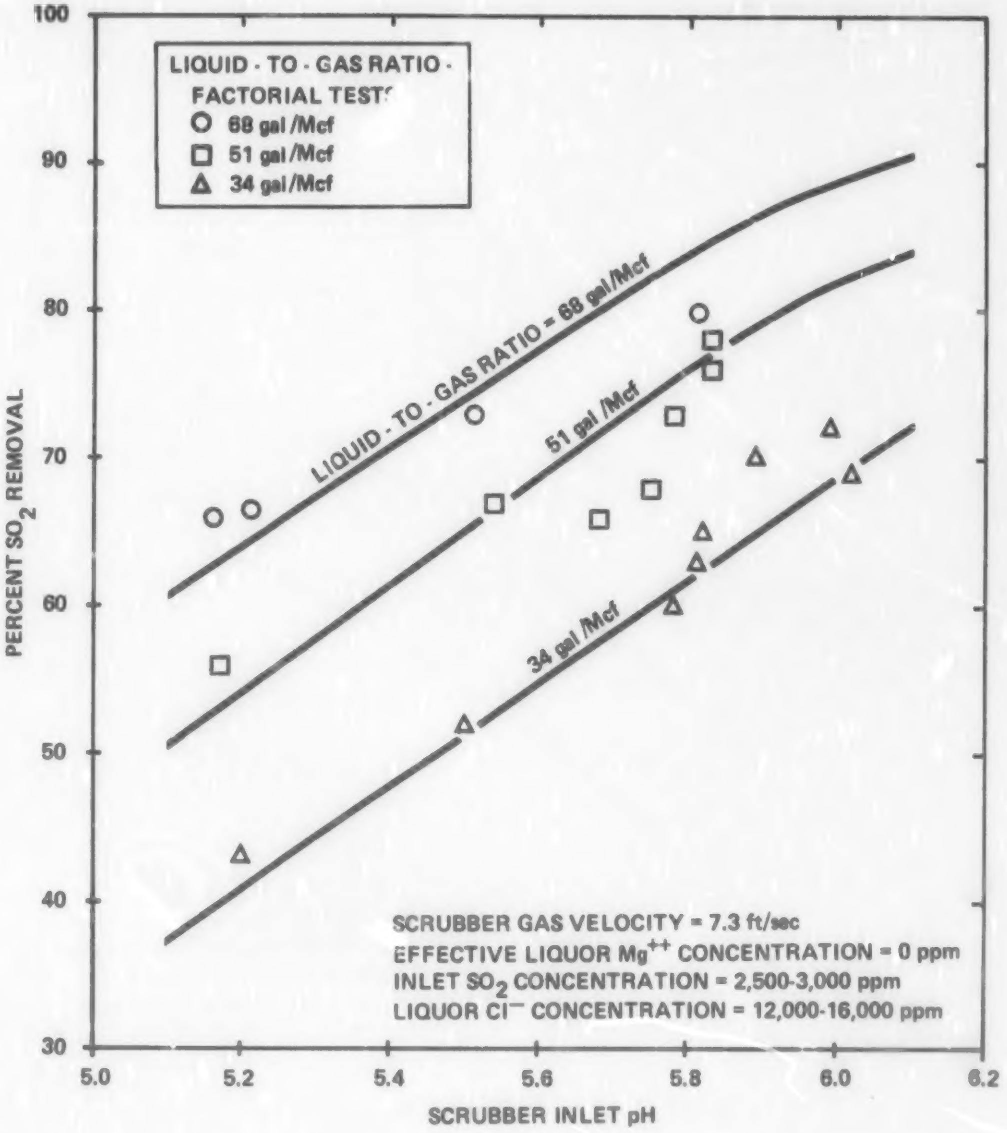


Figure 14-6. Scrubber Inlet pH and Liquid-to-Gas Ratio Versus Predicted (Equation 14-14) and Measured SO_2 Removal - Spray Tower with Limestone

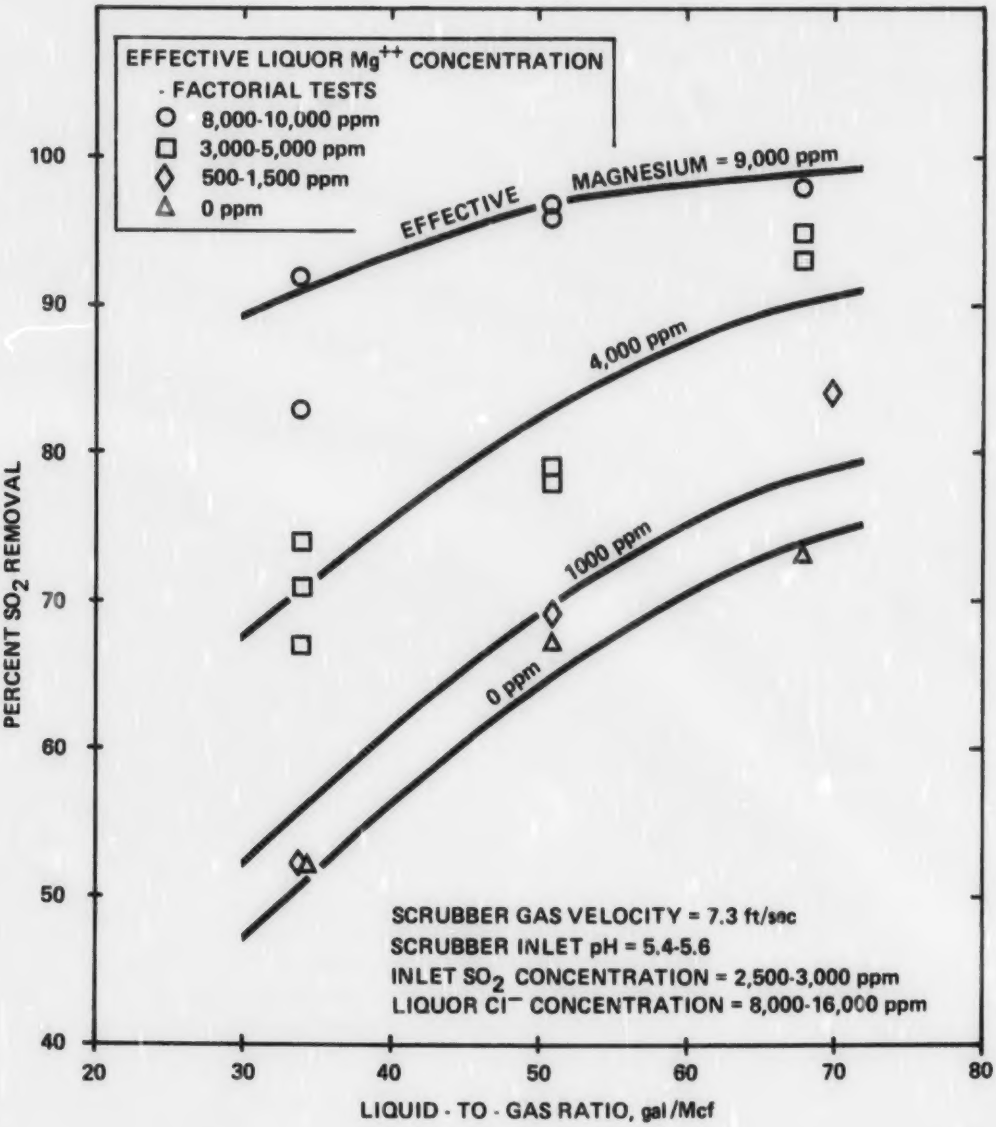


Figure 14-7. Liquid-to-Gas Ratio and Effective Magnesium Versus Predicted (Equation 14-14) and Measured SO_2 Removal - Spray Tower with Limestone

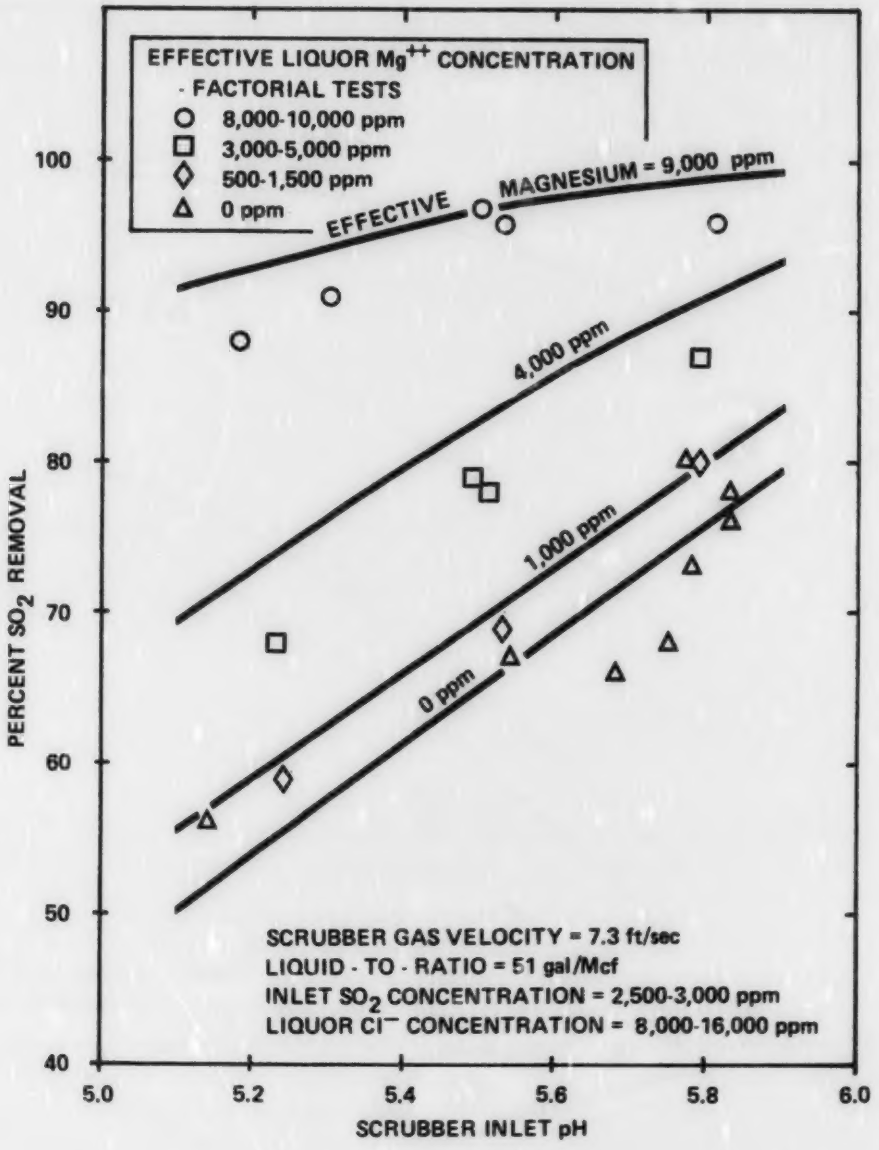


Figure 14-8. Scrubber Inlet pH and Effective Magnesium Versus Predicted (Equation 14-14) and Measured SO_2 Removal - Spray Tower with Limestone

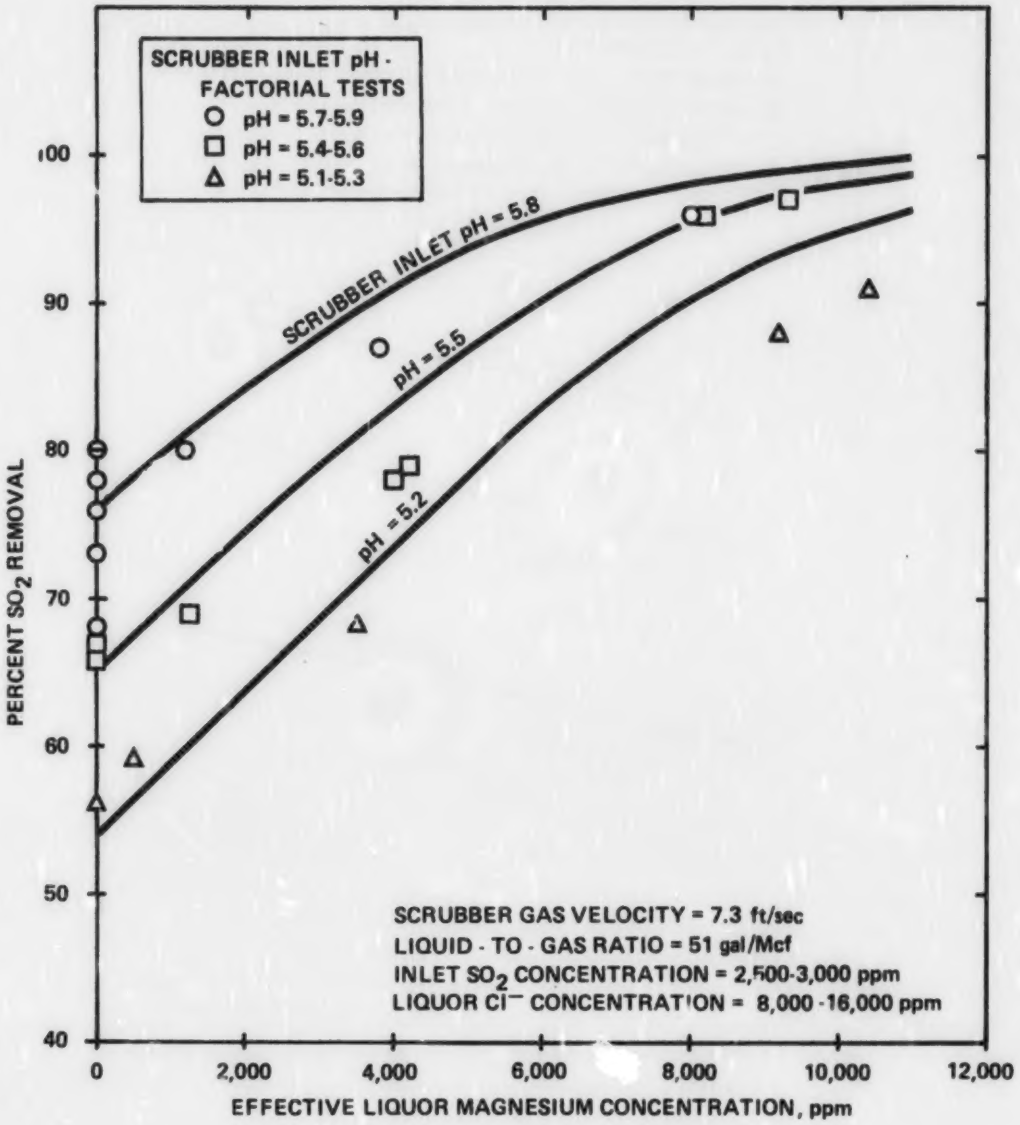


Figure 14-9. Effective Magnesium and Scrubber Inlet pH Versus Predicted (Equation 14-14) and Measured SO_2 Removal - Spray Tower with Limestone

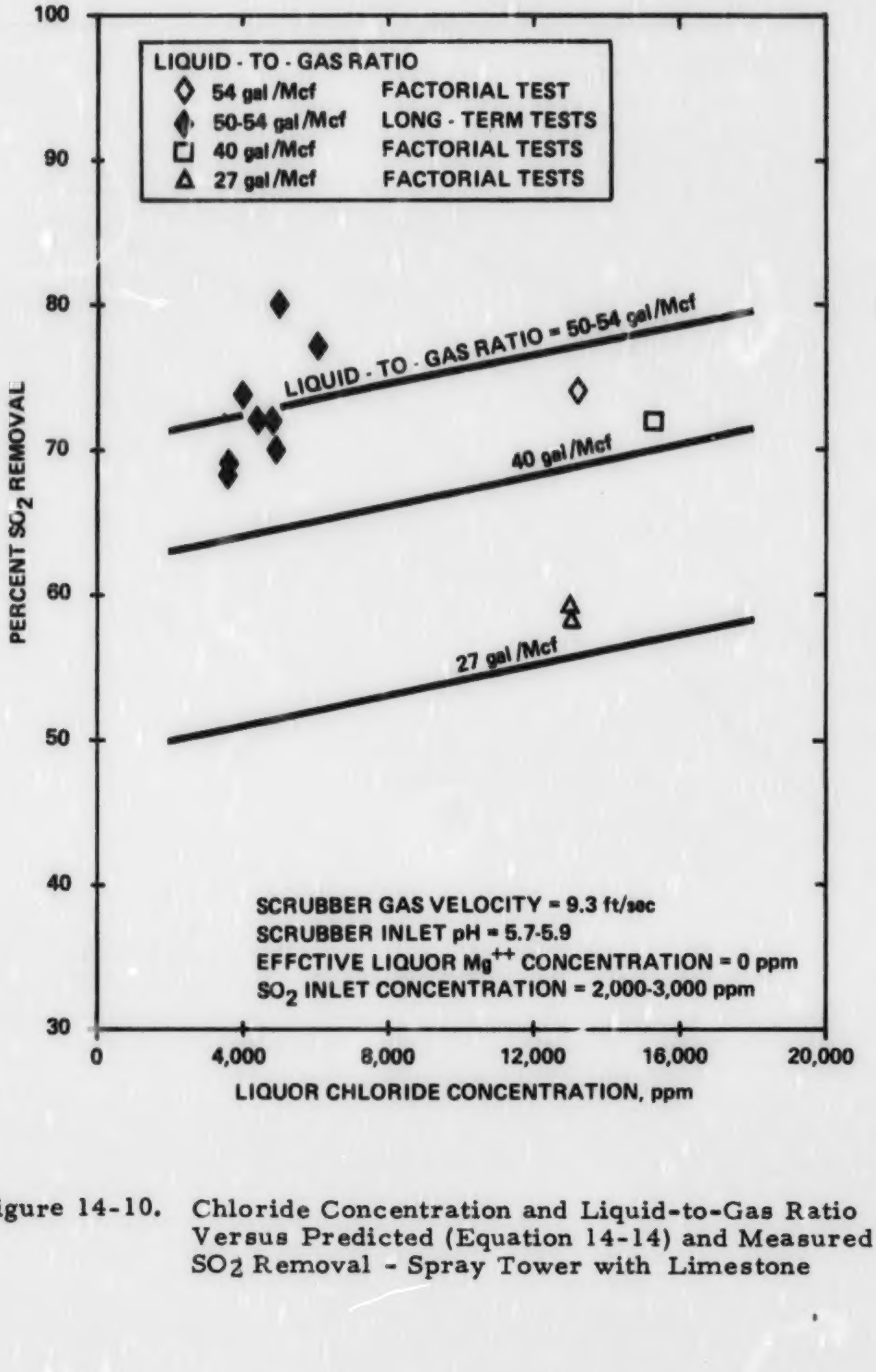


Figure 14-10. Chloride Concentration and Liquid-to-Gas Ratio Versus Predicted (Equation 14-14) and Measured SO_2 Removal - Spray Tower with Limestone

spray tower limestone data (with exceptions previously noted) - not just to the data points shown on a particular plot. Therefore, the predicted line for a small number of data points will not correspond to the best line through this subset of points.

A nomograph for the prediction of SO_2 removal is discussed in Subsection 14.4 and presented in Figure 14-33. This nomograph is based upon Equation 14-14.

14.2.4 TCA Equation for SO_2 Removal by Limestone Slurry

The following equation for SO_2 removal (having the form of Equation 14-10) has been fitted to all 100 TCA limestone and limestone/MgO factorial runs made during 1976 (see Section 9) and to 65 TCA long-term limestone runs made since October 1973 (Runs 525-2A through 589-2A):

$$\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\Bigg(-2.05 \times 10^{-4} (L/G)^{0.81} v^{0.36} \exp\Bigg[4.3 \times 10^{-3} v \left(\frac{h_{tot}}{d_s} + N_G\right) + 0.81\, pH_i + 7.9 \times 10^{-5} (Mg)_e - 1.7 \times 10^{-4} (SO_2)_i + 1.3 \times 10^{-5}\, Cl\Bigg]\Bigg) \qquad (14\text{-}15)$$

where

Cl = measured total dissolved chloride concentration, ppm

d_s = diameter of the TCA spheres (1.5 inches at Shawnee)

h_{tot} = total height of spheres in the TCA, inches

L/G = liquid-to-gas ratio in scrubber (125°F, humidified gas), gas/Mcf

$(Mg)_e$ = effective magnesium ion concentration, ppm
= [ppm Mg^{++} - (ppm $Cl^-/2.92$)] for $Mg^{++} > Cl^-/2.92$
= 0 for $Mg^{++} \leq Cl^-/2.92$
where 2.92 = ratio by weight of Cl^- to Mg^{++} in $MgCl_2$

N_G = number of grids or screens in the TCA (four at Shawnee)

pH_i = scrubber inlet liquor pH

$(SO_2)_i$ = inlet gas SO_2 concentration, ppm

v = gas velocity in the scrubber (125°F, humidified gas), ft/sec

The run averages of the variables used in Equation 14-15 are tabulated in Table 14-2.

The fitted ranges of the operating variables in Equation 14-15 are given below:

L/G	25-75 gal/Mcf
v	8.3-12.5 ft/sec
pH_i	5.1-6.1
$(Mg)_e$	0-11,000 ppm
$(SO_2)_i$	1500-4500 ppm
Cl	1500-21,000 ppm
d_s	1.5 inches
h_{tot}	0-22.5 inches
N_G	4

Table 14-2

RUN-AVERAGED TCA RESULTS FOR LIMESTONE SCRUBBING TO WHICH EQUATION 14-15 WAS FITTED

Run Number	Gas Velocity, fps	L/G, gal/Mcf	Total Height of Spheres, in.	Inlet pH	Effective Magnesium, ppm	Chloride Ion Conc., ppm	Inlet SO_2 Conc., ppm	SO_2 Removal, %
TCA-101	12.5	37.5	15.0	5.78	0	5700	2686	80
TCA-102	8.3	37.5	15.0	5.92	0	5700	2533	71
TCA-103	10.4	60.0	15.0	5.88	0	5700	2669	87
TCA-104	10.4	45.0	15.0	5.76	0	6000	2360	77
TCA-105	12.5	50.0	15.0	5.81	0	6300	2412	92
TCA-106	8.3	75.0	15.0	5.80	0	6300	2589	84
TCA-107	8.3	56.2	15.0	5.77	0	6300	2520	74
TCA-108	10.4	30.0	15.0	5.86	0	6300	2466	68
TCA-109	12.5	25.0	15.0	5.83	0	6300	2434	70
TCA-110	12.5	50.0	15.0	5.77	0	6650	2507	90
TCA-111	10.4	30.0	22.5	5.46	0	6000	2631	65
TCA-112	10.4	60.0	22.5	5.46	0	6500	2684	85
TCA-113	10.4	45.0	22.5	5.76	0	5500	2810	82
TCA-114	10.4	60.0	22.5	5.65	0	6100	2820	92
TCA-115	12.5	37.5	0.0	5.90	0	4900	2680	66
TCA-116	8.3	37.5	0.0	6.11	0	4600	2700	61
TCA-117	10.4	60.0	0.0	6.08	0	5000	2750	78
TCA-118	10.4	45.0	0.0	6.01	0	5400	2920	64
TCA-119	12.5	50.0	0.0	5.85	0	5800	2909	70
TCA-120	8.3	75.0	0.0	5.84	0	5750	2920	71
TCA-121	8.3	56.2	0.0	5.89	0	5850	2725	63
TCA-122	10.4	30.0	0.0	5.86	0	6000	2743	46
TCA-123	12.5	25.0	0.0	5.75	0	6200	2755	47
TCA-124	12.5	50.0	0.0	5.82	0	5700	2743	60
TCA-125	10.4	60.0	15.0	5.55	0	7000	2427	78
TCA-126	10.4	30.0	15.0	5.52	0	6500	2672	61
TCA-127	10.4	45.0	15.0	5.52	0	6500	2623	74
TCA-128	10.4	60.0	15.0	5.28	0	7000	2749	71
TCA-129	10.4	30.0	15.0	5.18	0	7100	2520	49
TCA-130	10.4	45.0	15.0	5.33	0	6900	2440	67
TCA-131	10.4	60.0	15.0	5.01	0	7000	2513	66
TCA-132	10.4	60.0	22.5	5.24	0	6700	2720	70
TCA-133	10.4	60.0	0.0	5.19	0	6400	2440	51
TCA-134	10.4	45.0	15.0	5.82	0	7300	2688	79
TCA-135	12.5	50.0	15.0	5.92	0	6000	2593	95
TCA-136	8.3	37.5	15.0	5.79	0	5300	2544	68
TCA-137	10.4	45.0	15.0	5.75	0	5900	2543	79
TCA-138	10.4	45.0	15.0	5.04	0	6500	2747	60
TCA-139	10.4	45.0	15.0	4.93	0	6500	2785	57
TCA-140	10.4	60.0	0.0	5.84	0	8450	2606	67
TCA-141	8.3	37.5	0.0	5.84	0	8100	2554	52
TCA-142	10.4	45.0	0.0	5.80	0	7750	2566	57
TCA-143	12.5	37.5	0.0	5.78	0	8800	2685	59
TCA-144	8.3	37.5	15.0	5.85	0	7500	2473	70
TCA-145	10.4	60.0	15.0	5.28	0	8150	2360	72
TCA-146	10.4	60.0	0.0	5.51	0	7400	2450	57
TCA-147	10.4	60.0	0.0	5.24	0	8800	2583	50
TCA-148	10.4	45.0	0.0	5.24	0	8500	2647	45
TCA-149	10.4	45.0	0.0	5.51	0	8500	2765	52
TMG-101	10.4	45.0	15.0	5.55	0	18470	2380	74
TMG-102	10.4	60.0	15.0	5.44	0	21210	2530	79

Table 14-2 (continued)

RUN-AVERAGED TCA RESULTS FOR LIMESTONE SCRUBBING TO WHICH EQUATION 14-15 WAS FITTED

Run Number	Gas Velocity, fps	L/G, gal/ Mcf	Total Height of Spheres, in.	Inlet pH	Effective Magnesium, ppm	Chloride Ion Conc., ppm	Inlet SO_2 Conc., ppm	SO_2 Removal, %
TMG-103	10.4	30.0	15.0	5.49	0	20650	2540	64
TMG-104	12.5	37.5	15.0	5.55	0	21075	2443	80
TMG-105	10.4	45.0	15.0	5.15	0	13520	2425	64
TMG-106	10.4	60.0	15.0	5.20	0	13930	2511	74
TMG-107	10.4	30.0	15.0	5.22	0	13550	2409	56
TMG-108	10.4	45.0	15.0	5.19	0	14210	2429	67
TMG-109	10.4	45.0	15.0	5.76	0	14090	2517	85
TMG-119	10.4	45.0	15.0	5.51	8	14075	2580	74
TMG-120	12.5	37.5	15.0	5.52	28	13970	2577	77
TMG-121	10.4	45.0	15.0	5.23	374	13000	2614	60
TMG-122	10.4	45.0	15.0	5.80	239	13000	2467	80
TMG-138	8.3	56.2	15.0	5.49	490	13850	2406	71
TMG-151	10.4	60.0	15.0	5.52	281	13600	2553	77
TMG-152	10.4	30.0	15.0	5.51	441	13600	2413	54
TMG-153	10.4	45.0	15.0	5.24	616	13500	2326	58
TMG-154	10.4	60.0	15.0	5.23	975	12900	2389	69
TMG-155	10.4	30.0	15.0	5.19	655	13400	2355	46
TMG-156	10.4	45.0	0.0	5.25	1238	11770	3064	49
TMG-157	10.4	45.0	0.0	5.51	1436	10650	3126	57
TMG-158	10.4	45.0	0.0	5.84	862	9638	3168	67
TMG-159	10.4	45.0	0.0	5.49	4502	13064	3176	65
TMG-160	10.4	45.0	0.0	5.23	4212	14334	2167	69
TMG-161	10.4	45.0	0.0	5.79	5276	13242	2808	75
TMG-162	10.4	60.0	0.0	5.52	5285	12965	3330	80
TMG-163	10.4	30.0	0.0	5.48	4721	12376	3383	57
TMG-164	10.4	45.0	0.0	5.56	5443	11766	3560	64
TMG-165	10.4	45.0	15.0	5.52	4958	13100	2550	82
TMG-166	12.5	37.5	15.0	5.53	4339	14100	2632	86
TMG-167	10.4	45.0	15.0	5.26	4008	15700	2456	77
TMG-168	8.3	56.2	15.0	5.51	3679	15400	2213	86
TMG-169	10.4	45.0	15.0	5.78	3759	14800	2246	91
TMG-170	10.4	45.0	15.0	5.53	4316	15000	2180	87
TMG-171	12.5	37.5	15.0	5.50	4036	16170	2225	90
TMG-172	10.4	45.0	15.0	5.78	8314	14380	2347	97
TMG-173	10.4	45.0	15.0	5.51	8204	13500	2313	96
TMG-174	10.4	60.0	15.0	5.52	8753	12434	2345	97
TMG-175	10.4	30.0	15.0	5.47	9682	12957	2280	76
TMG-176	12.5	37.5	15.0	5.49	9614	13000	2336	94
TMG-177	10.4	45.0	15.0	5.24	8915	12250	2367	88
TMG-178	10.4	60.0	15.0	5.22	7313	16819	2380	92
TMG-179	10.4	30.0	15.0	5.20	7505	15175	2376	72
TMG-180	10.4	45.0	15.0	5.81	6777	14209	2234	95
TMG-181	10.4	45.0	0.0	5.76	7959	13206	2680	81
TMG-182	10.4	45.0	0.0	5.53	8395	13246	2260	78
TMG-183	10.4	45.0	0.0	5.22	8609	14413	2683	74
TMG-184	10.4	45.0	15.0	5.54	7279	14733	2480	92
TMG-185	12.5	25.0	15.0	5.48	8762	15943	2420	86
TMG-186	10.4	45.0	0.0	5.80	8872	14057	2847	87
TMG-187	10.4	45.0	0.0	5.47	4869	13905	2155	72

Table 14-2 (continued)

RUN-AVERAGED TCA RESULTS FOR LIMESTONE SCRUBBING TO WHICH EQUATION 14-15 WAS FITTED

Run Number	Gas Velocity, fps	L/G, gal/Mcf	Total Height of Spheres, in.	Inlet pH	Effective Magnesium, ppm	Chloride Ion Conc., ppm	Inlet SO_2 Conc., ppm	SO_2 Removal, %
525-2A	10.4	60.0	15.0	5.80	0	3200	2900	81
526-2A	8.5	73.2	15.0	5.78	0	3700	2950	81
527-2A	8.5	73.2	15.0	5.83	0	3001	3200	80
528-2A	8.5	73.2	15.0	5.83	0	1600	3000	85
529-2A	8.5	73.2	15.0	5.80	0	3300	3100	84
530-2A	8.5	73.2	15.0	5.85	0	2790	3200	84
531-2A	8.5	73.2	15.0	5.75	0	3100	2750	84
532-2A	8.5	73.2	15.0	5.80	9678	2400	2950	98
533-2A	8.5	73.2	15.0	5.85	10738	3100	2875	97
534-2A	8.5	73.2	15.0	5.75	0	3001	3150	83
535-2A	8.5	73.2	15.0	5.90	0	3000	3000	82
535-2B	8.5	73.2	15.0	5.95	0	1510	3200	80
536-2A	10.0	62.5	15.0	5.90	0	1500	2750	80
537-2A	10.0	72.9	15.0	5.90	0	2001	2750	87
538-2A	10.0	72.9	15.0	5.90	0	2010	3100	89
539-2A	12.0	43.4	15.0	6.00	0	1940	2950	87
540-2A	12.0	43.4	15.0	6.00	0	2001	3100	89
541-2A	12.0	43.4	15.0	5.85	0	2001	3350	84
542-2A	12.0	43.4	15.0	5.88	0	2001	3550	80
543-2A	12.0	43.4	15.0	5.85	0	2001	3050	80
544-2A	8.5	73.2	15.0	5.95	0	2010	3190	84
545-2A	12.0	43.4	15.0	5.90	0	2001	3100	83
546-2A	12.5	41.7	15.0	5.85	0	2220	3050	84
547-2A	12.5	41.7	15.0	5.95	0	2001	3000	82
548-2A	12.5	41.7	15.0	6.00	0	2001	2500	83
549-2A	12.5	41.7	15.0	5.90	0	2001	2650	77
550-2A	12.5	41.7	15.0	5.80	0	2001	2700	76
551-2A	12.5	41.7	15.0	5.90	0	2001	2900	78
552-2A	12.5	50.0	15.0	5.99	0	2001	3150	82
553-2A	12.5	50.0	15.0	5.80	0	2001	2400	82
554-2A	9.4	66.7	15.0	6.02	0	2001	2650	80
555-2A	9.4	66.7	15.0	5.95	0	2001	2200	80
556-2A	9.4	66.7	15.0	6.00	0	2001	2100	81
557-2A	12.5	50.0	15.0	5.90	0	1690	2250	85
558-2A	12.5	50.0	15.0	5.83	0	1660	2700	76
559-2A	12.5	50.0	15.0	5.90	0	1770	3050	77
560-2A	12.5	50.0	15.0	5.75	0	1970	3300	76
561-2A	12.5	50.0	15.0	5.95	0	2600	3000	77
562-2A	12.5	50.0	15.0	5.90	0	2700	3000	80
562-2B	12.5	50.0	15.0	5.70	0	2980	3250	80
563-2A	12.5	50.0	15.0	5.90	0	2070	3300	86
564-2A	12.5	50.0	15.0	5.20	0	1960	3250	56
565-2A	12.5	41.7	15.0	5.20	0	1800	3550	57
566-2A	12.5	41.7	15.0	5.85	0	2490	3250	82
567-2A	12.5	41.7	15.0	6.00	0	2020	2700	85
568-2A	12.5	41.7	15.0	5.50	0	1790	3200	63
569-2A	12.5	41.7	15.0	5.50	0	2060	3100	67
569-2B	12.5	41.7	15.0	5.50	0	1880	3100	64
570-2A	12.5	41.7	15.0	5.75	0	2310	3000	70
571-2A	12.5	41.7	15.0	5.85	0	2900	2900	74
572-2A	12.5	41.7	15.0	5.23	0	3050	3150	55
573-2A	12.5	41.7	15.0	5.50	0	3890	2750	63
575-2A	12.5	41.7	15.0	5.45	0	3590	3000	70
576-2A	12.5	41.7	15.0	5.65	0	3910	3250	72
577-2A	12.5	41.7	15.0	5.78	0	3490	3300	82
579-2A	12.5	41.7	15.0	5.20	0	3260	3200	61
581-2A	12.5	50.0	24.0	5.45	0	3430	2750	85
583-2A	12.5	50.0	15.0	5.45	0	8031	3050	77
583-2B	12.5	50.0	15.0	5.30	5166	3847	2900	84
584-2A	12.5	50.0	15.0	5.40	9184	5010	2950	94
585-2A	12.5	37.5	15.0	5.40	9141	4230	2900	85
586-2A	12.5	50.0	0.0	5.30	8570	4380	2750	80
587-2A	12.5	50.0	15.0	5.30	9032	2010	3100	93
588-2A	8.5	73.2	15.0	5.35	9108	6400	2550	94
589-2A	12.5	50.0	15.0	5.45	9167	3600	3600	90

Extrapolations with TCA Equation 14-15 are not recommended, unless the possibility of flooding (high-pressure drop) or other unstable operating conditions is first discounted.

For constant stoichiometry and effluent residence time, an increase in the number of effluent hold tanks (so that slurry flow through the tanks approaches plug flow) has been observed to increase both SO_2 removal and pH_i. The pH_i term in Equation 14-15 accounts for such an increase in SO_2 removal, and no additional term is required for the number of tanks.

In Equation 14-15, the coefficient of the inlet gas SO_2 concentration term, -1.7×10^{-4}, was obtained from individual Shawnee long-term data points and from EPA and TVA pilot scrubber data (see Subsection 14.2.1).

Measured SO_2 removals and those predicted from Equation 14-15 are shown in Figure 14-11. Equation 14-15 accounts for 89 percent of the variation in the combined data (93 percent for the factorial data and 74 percent for the long-term data), with a standard error of estimate of 4.1 percent SO_2 removal (3.7 percent for the factorial data and 5.0 percent for the long-term data).

Figures 14-12 through 14-19 are parametric plots derived from Equa-

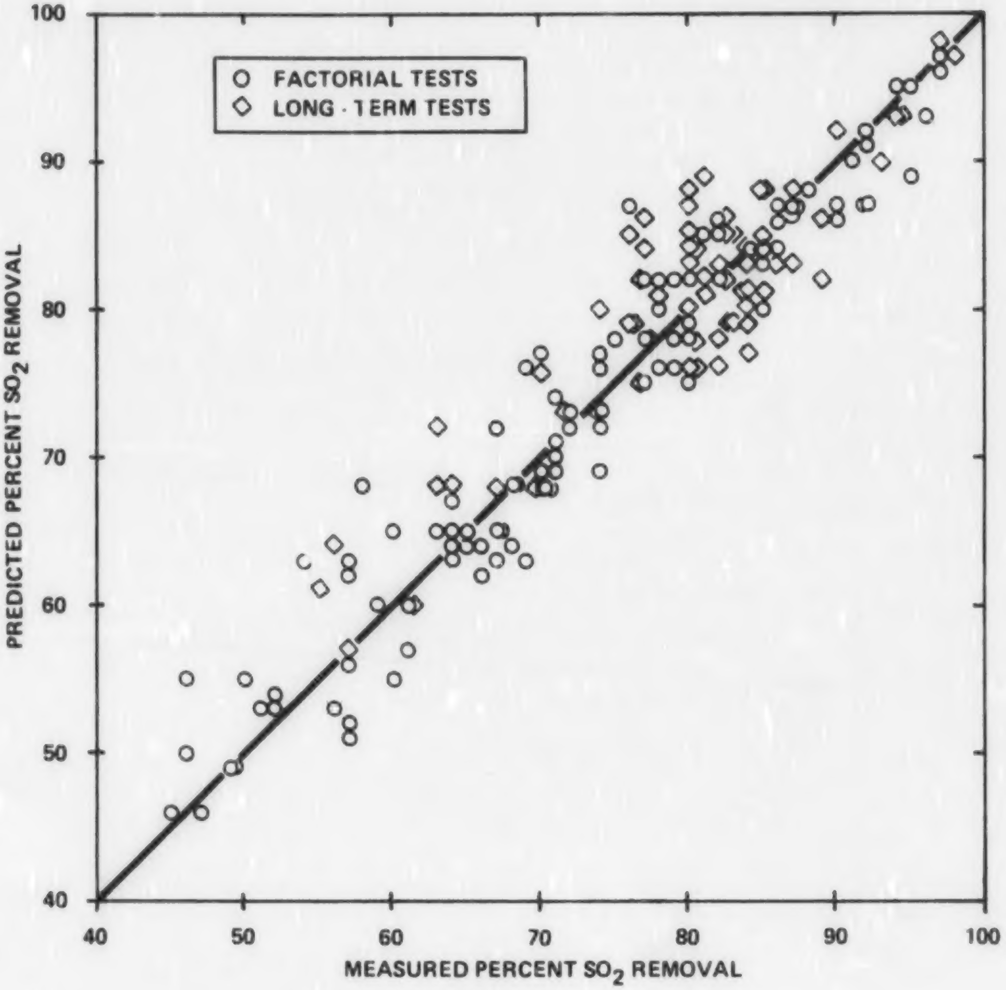


Figure 14-11. Comparison of Experimental Data and Predicted Values (Equation 14-15) of SO_2 Removal - TCA with Limestone

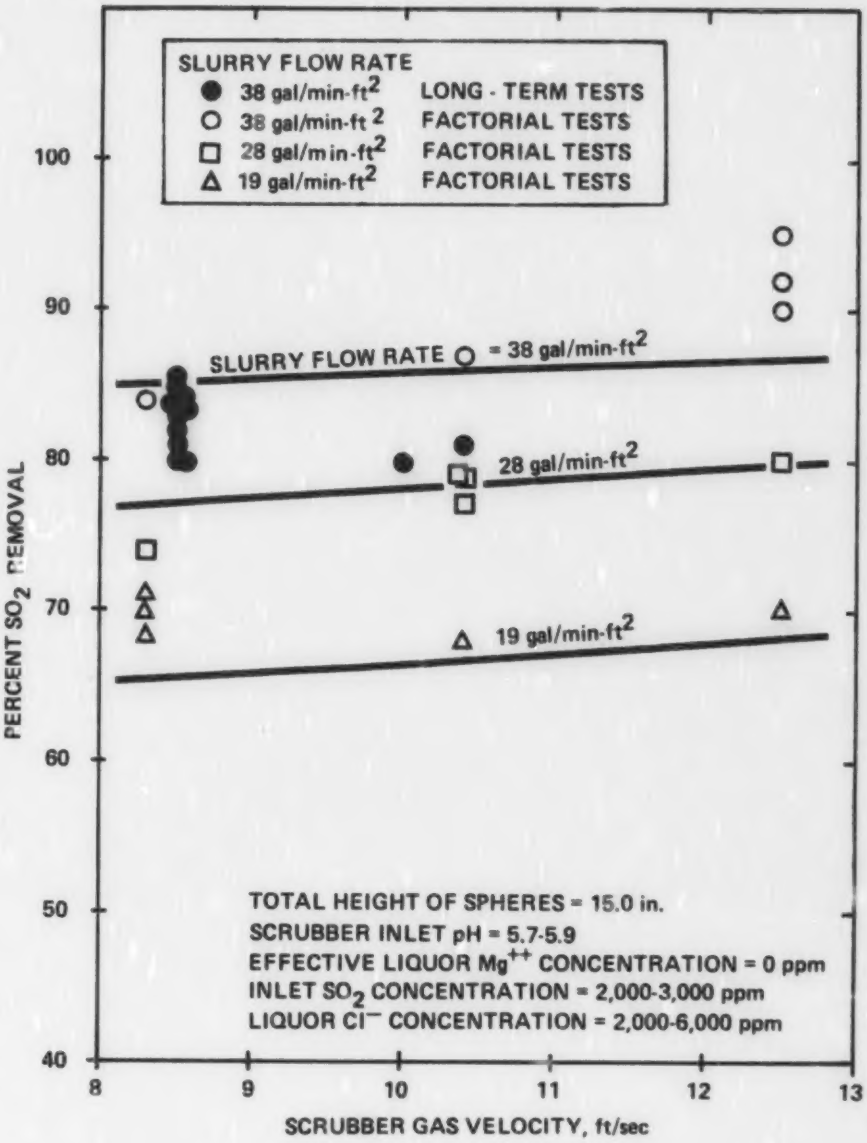


Figure 14-12. Gas Velocity and Slurry Flow Rate Versus Predicted (Equation 14-15) and Measured SO_2 Removal - TCA with Limestone

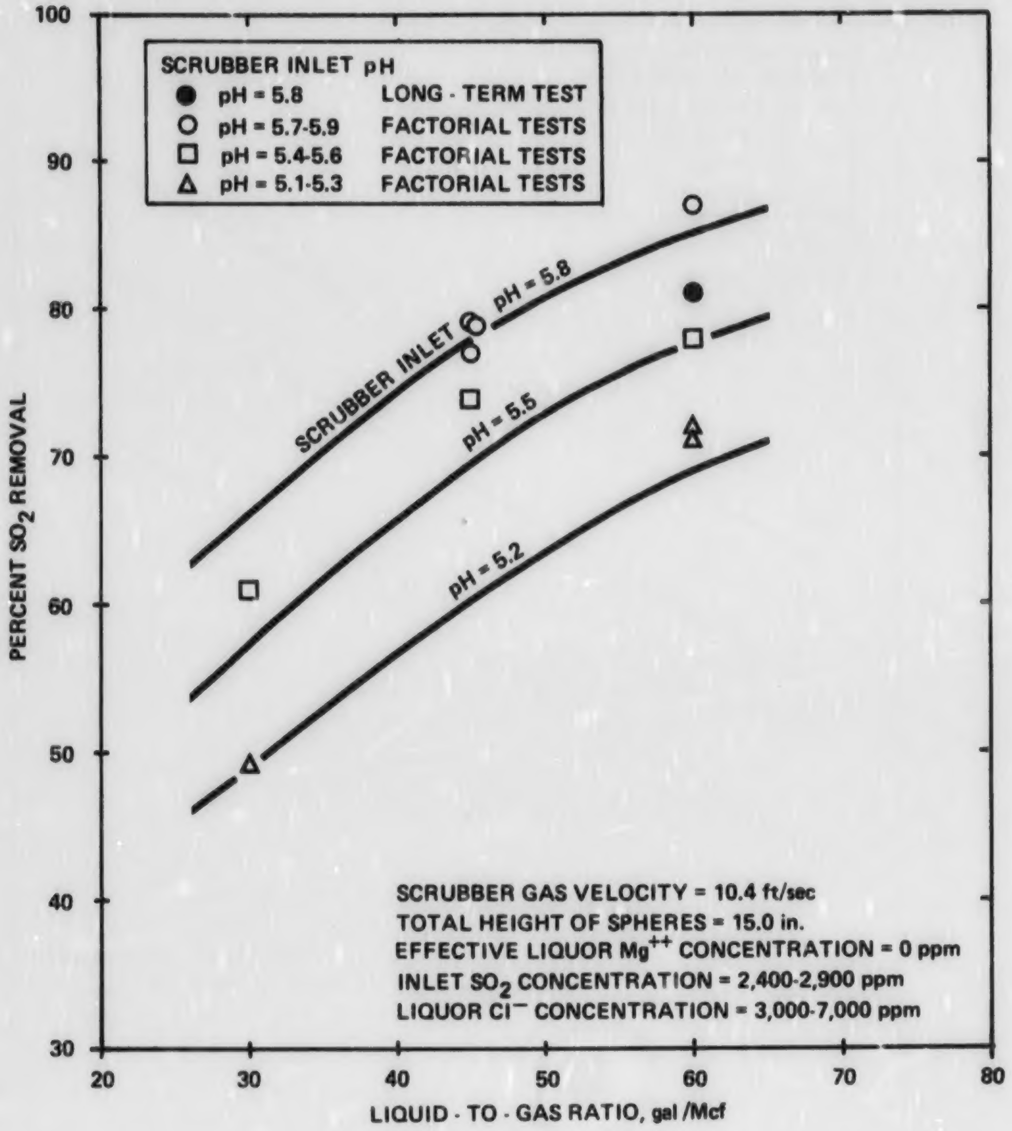


Figure 14-13. Liquid-to-Gas Ratio and Scrubber Inlet pH Versus Predicted (Equation 14-15) and Measured SO_2 Removal - TCA with Limestone

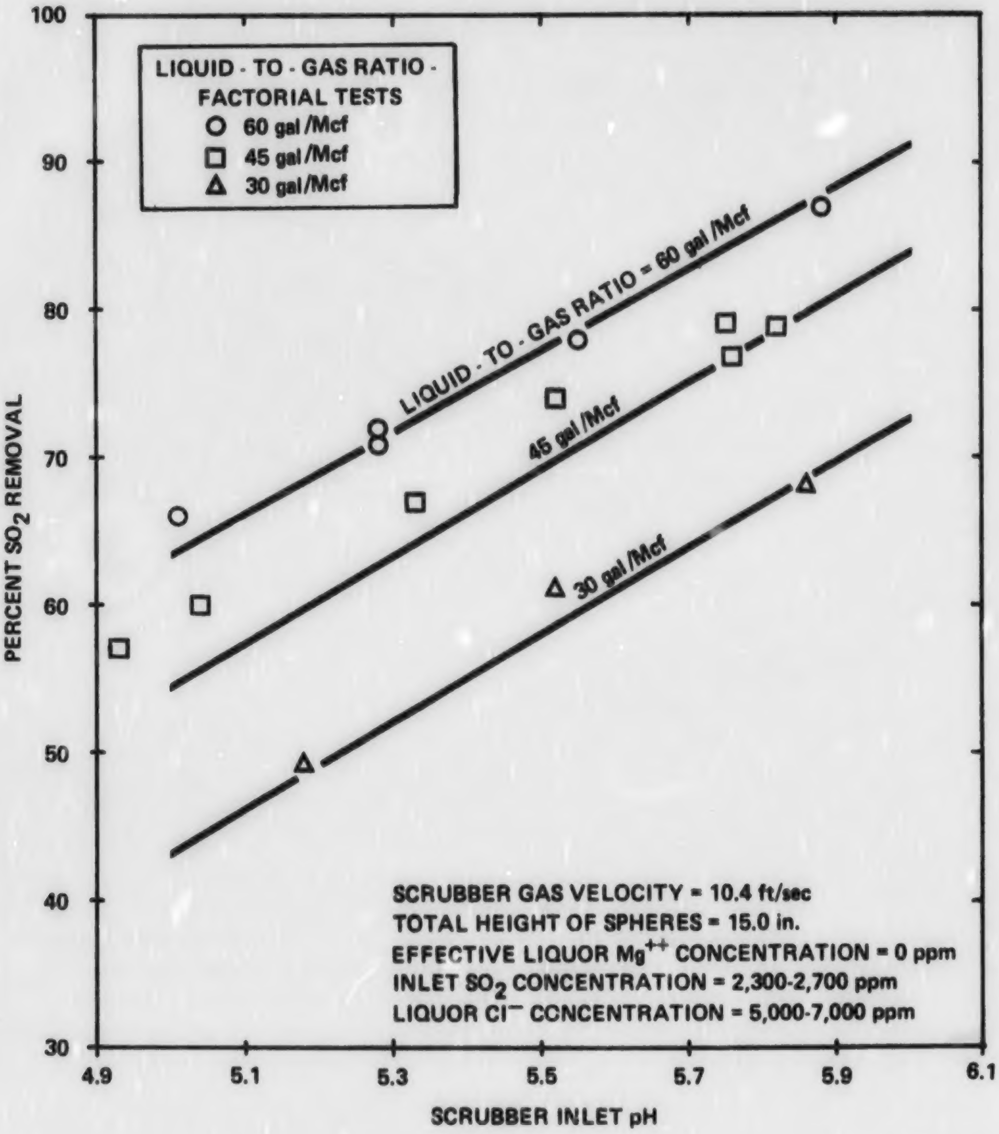


Figure 14-14. Scrubber Inlet pH and Liquid-to-Gas Ratio Versus Predicted (Equation 14-15) and Measured SO_2 Removal - TCA with Limestone

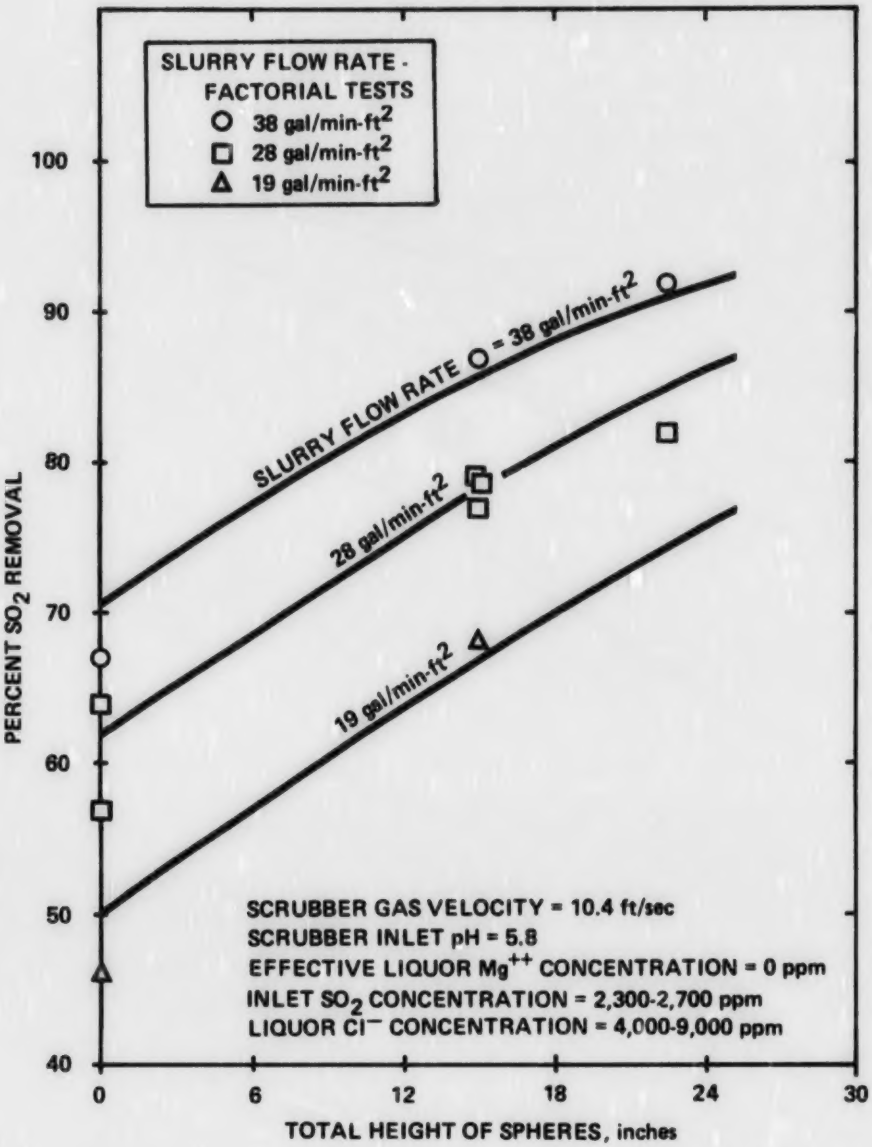


Figure 14-15. Total Height of Spheres and Slurry Flow Rate Versus Predicted (Equation 14-15) and Measured SO_2 Removal - TCA with Limestone

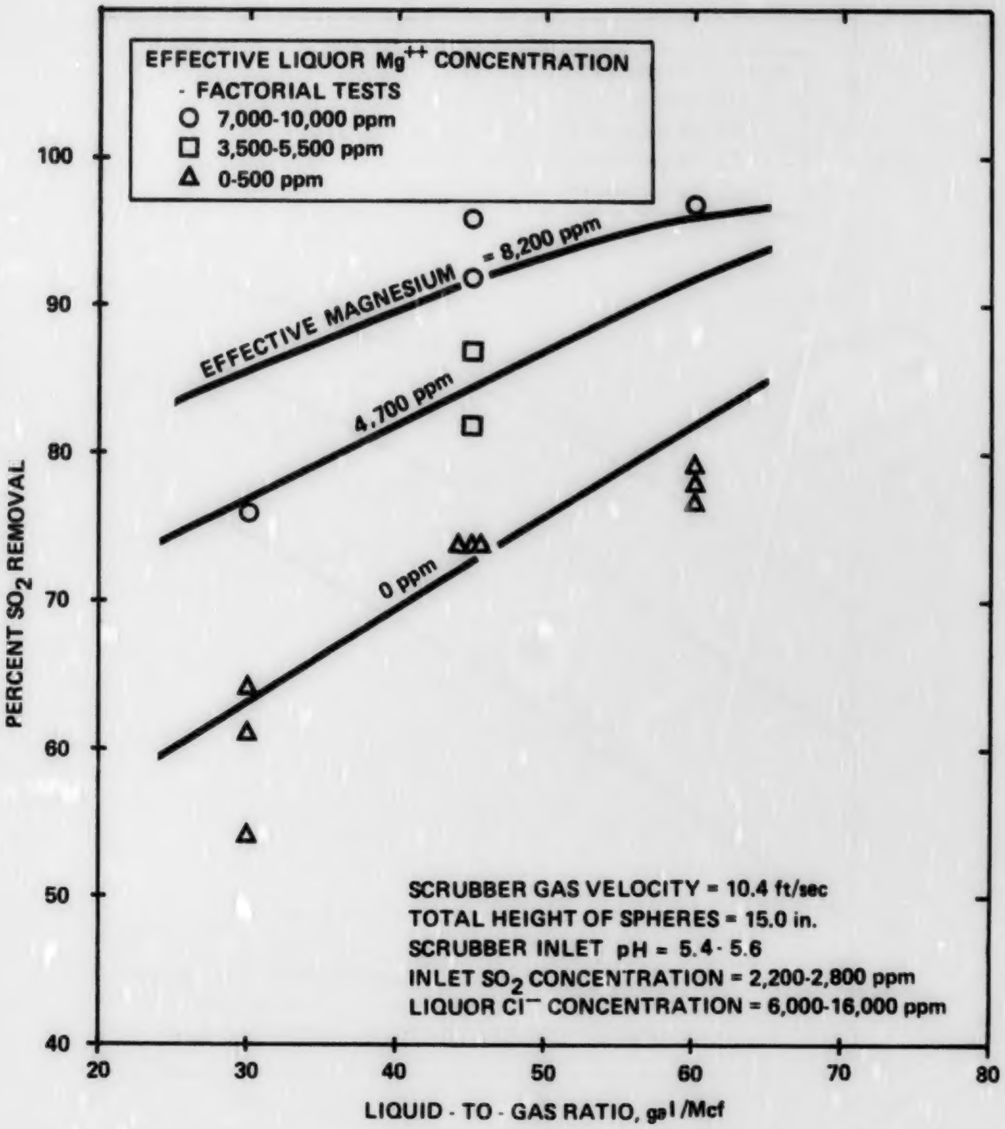


Figure 14-16. Liquid-to-Gas Ratio and Effective Magnesium Versus Predicted (Equation 14-15) and Measured SO_2 Removal - TCA with Limestone

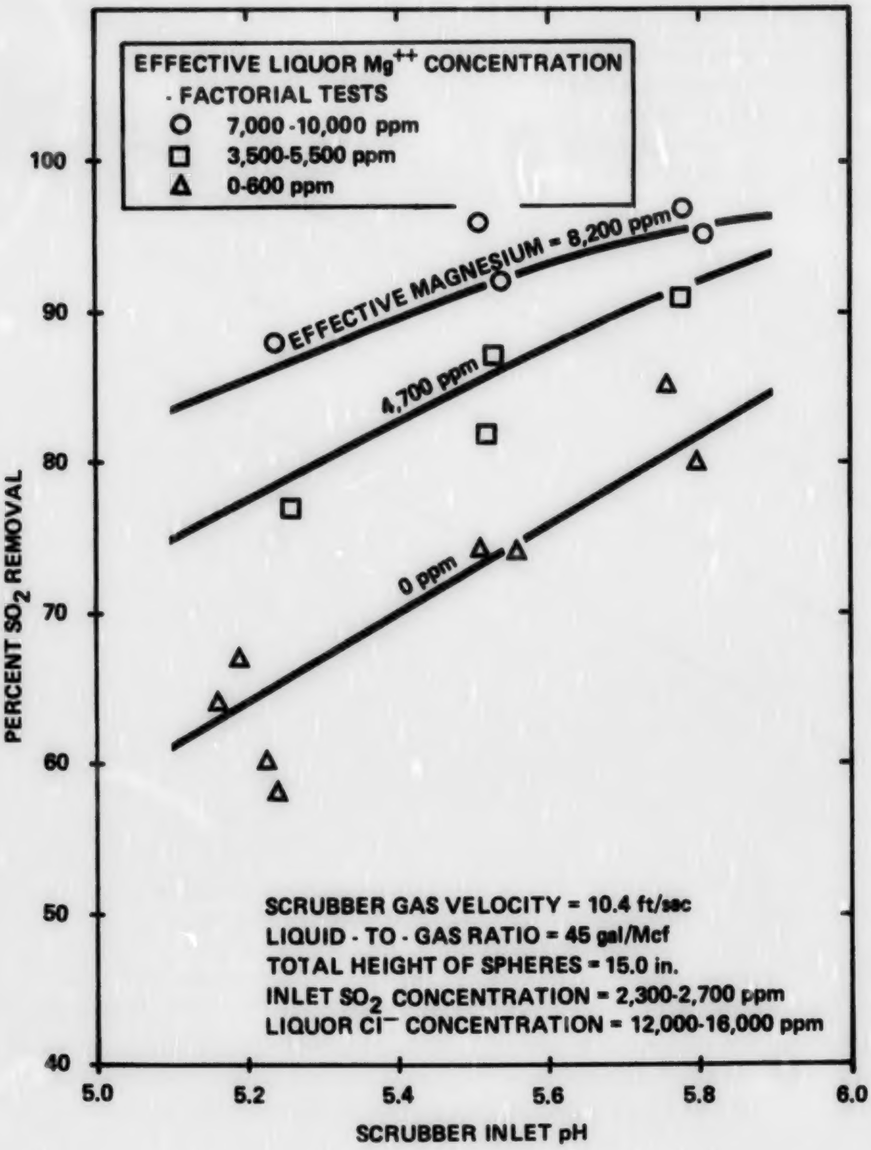


Figure 14-17. Scrubber Inlet pH and Effective Magnesium Versus Predicted (Equation 14-15) and Measured SO_2 Removal - TCA with Limestone

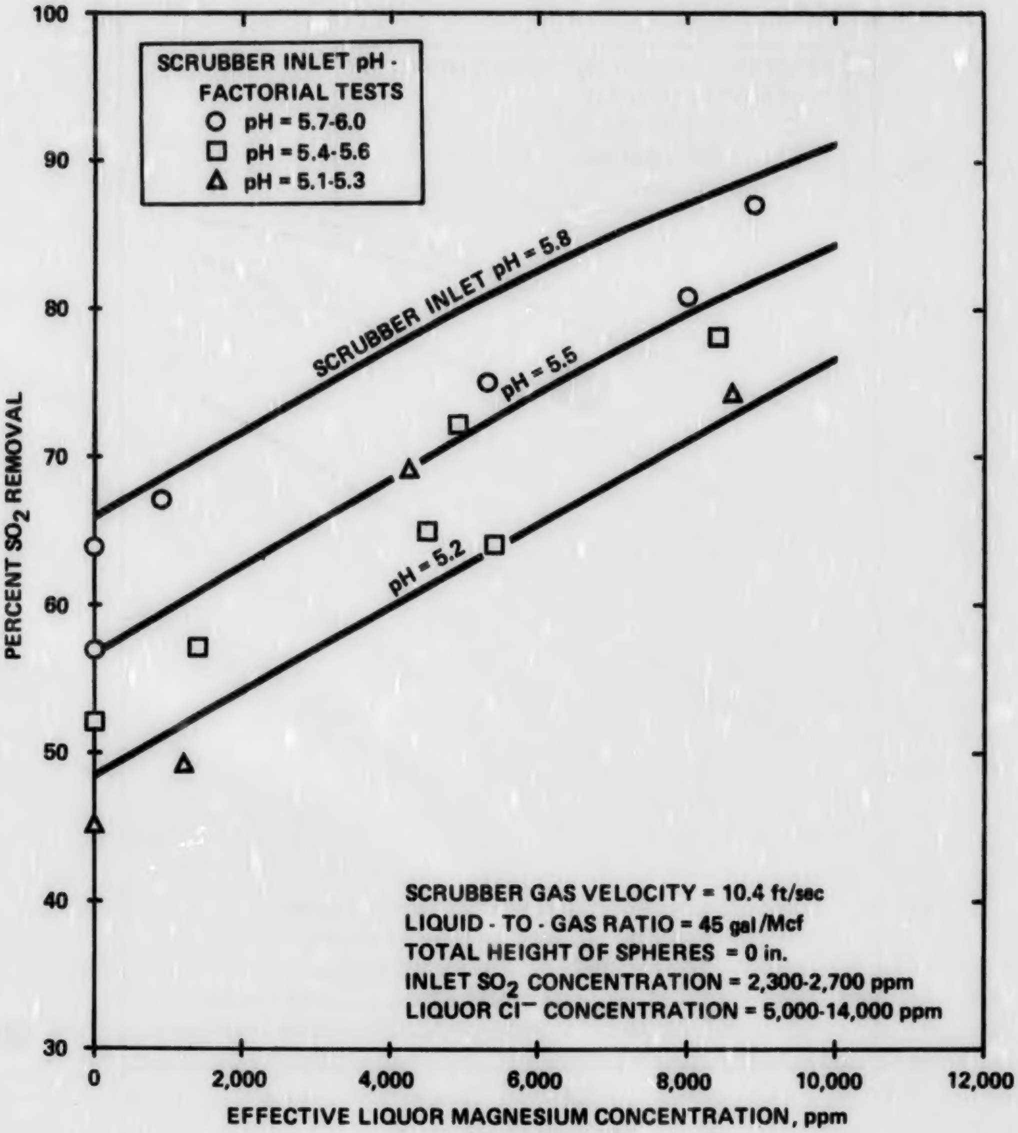


Figure 14-18. Effective Magnesium and Scrubber Inlet pH Versus Predicted (Equation 14-15) and Measured SO_2 Removal - TCA (No Spheres) with Limestone

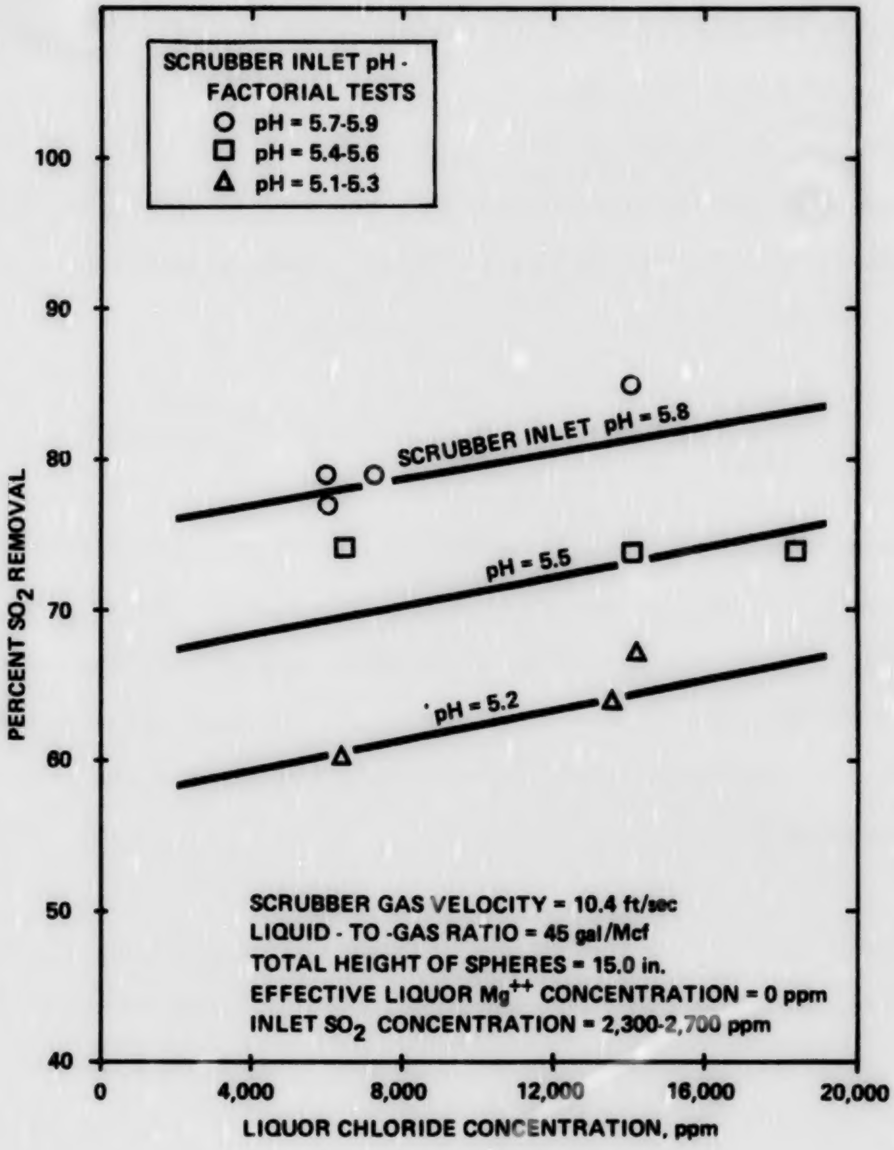


Figure 14-19. Chloride Concentration and Scrubber Inlet pH Versus Predicted (Equation 14-15) and Measured SO_2 Removal - TCA with Limestone

tion 14-15 showing predicted SO_2 removals and the corresponding Shawnee TCA limestone data.

A nomograph for the prediction of SO_2 removal is discussed in Subsection 14.4 and shown in Figure 14-34. This nomograph is based upon Equation 14-15.

14.3 FITTED EQUATIONS FOR SO_2 REMOVAL BY LIME SLURRY

In this subsection two equations for SO_2 removal by lime slurry are presented -- one for the spray tower and one for the TCA -- and parametric plots based on these equations are shown. These equations have the form of Equation 14-10 and were fitted to run-averaged Shawnee factorial and long-term test data. Nomographs are presented in Subsection 14.4.

For these lime tests, the effects of dissolved magnesium, dissolved chloride, and inlet gas SO_2 concentration on SO_2 removal are somewhat uncertain because of limited operating ranges and a tendency for these effects to be statistically confused with, or masked by each other. Therefore, the equations presented in this subsection should not be extrapolated beyond the Shawnee operating ranges.

14.3.1 Spray Tower Equation for SO_2 Removal by Lime Slurry

The following equation for SO_2 removal in the spray tower has been fitted to the 25 spray tower lime factorial runs made during 1976 (see Section 6) and to 34 long-term lime runs, 7 with the spray tower only (venturi at minimum pressure drop) and 27 with both the venturi and spray tower (Runs 601-1A through VFG-1D):

$$\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\left\{-0.0020\,(L/G)\exp\left[0.29\,pH_i + 2.8\times10^{-4}\,(Mg)_e + 4.7\times10^{-5}\,Cl\right]\right\} \quad (14\text{-}16)$$

where

Cl = measured total dissolved chloride concentration, ppm

L/G = liquid-to-gas ratio in the scrubber (125°F, humidified gas) gal/Mcf

$(Mg)_e$ = effective magnesium ion concentration, ppm
= [ppm Mg^{++} - (ppm Cl^-/2.92)] for $Mg^{++} > Cl^-/2.92$
= 0 for $Mg^{++} \leq Cl^-/2.92$
where 2.92= ratio by weight of Cl^- to Mg^{++} in $MgCl_2$

pH_i = scrubber inlet liquor pH

The run averages of the variables used in Equation 14-16 are tabulated in Table 14-3.

Table 14-3

RUN-AVERAGED SPRAY TOWER RESULTS FOR LIME SCRUBBING TO WHICH EQUATION 14-16 WAS FITTED

Run Number	Slurry Flow Rate, gpm	Gas Velocity, fps	L/G, gal/Mcf	Inlet pH	Effective Magnesium, ppm	Chloride Ion Conc. ppm	SO_2 Removal, %
VST-017	1125	9.4	40	8.05	0	9000	73
VST-018	750	9.4	27	7.96	0	12600	58
VST-019	1500	5.4	94	8.10	0	4900	95
VST-020	1125	7.4	51	8.02	0	9500	84
VST-021	1125	5.4	70	8.04	0	8500	90
VST-022	750	9.4	27	8.08	0	12500	59
VST-023	1500	7.4	68	8.01	0	13100	87
VST-024	1500	9.4	54	8.05	0	6700	77
VST-025	1125	7.4	51	8.08	0	9500	82
VST-026	750	5.4	47	8.05	0	12750	77
VST-027	1500	5.4	94	8.04	0	6500	95
VST-028	750	7.4	34	8.03	0	12200	65
VST-029	1125	7.4	51	6.78	0	10550	71
VST-030	1125	7.4	51	9.08	0	10600	95
VST-031	1125	7.4	51	6.11	0	10500	67
VST-032	1125	7.4	51	8.08	0	11350	81
VST-033	1125	7.4	51	6.08	0	12100	67
VST-035	750	7.4	34	8.01	0	13000	65
VST-037	750	7.4	34	8.20	0	11400	69
VST-039	750	7.4	34	8.00	0	11650	75
VST-040	1125	7.4	51	8.01	0	5000	73
VST-041	1125	7.4	51	8.05	0	12150	85
VST-042	1125	7.4	51	8.06	0	6400	71
VST-044(1)	1200	9.4	43	8.05	0	6600	71
VST-047	1125	7.4	51	9.07	0	11900	97
601-1A (1)	1200	6.7	60	8.00	0	3300	75
602-1A (1)	1200	6.7	60	7.95	0	4600	87
603-1A (1)	1200	6.7	60	8.00	0	4770	88
604-1A	1200	6.7	60	8.05	0	5700	81
605-1A	1200	6.7	60	9.00	0	3070	77
606-1A	1200	6.7	60	8.00	0	3500	73
608-1A (1)	1200	6.7	60	8.00	0	3900	78
609-1A (1)	1200	6.7	60	8.10	0	4200	82
610-1A (1)	1200	6.7	60	8.10	0	5200	89
618-1A	1200	6.7	60	7.65	0	1130	68
619-1A (1)	1200	6.7	60	7.80	0	2920	77
621-1A (1)	1200	6.7	60	8.05	0	3400	83
622-1A (1)	1200	6.7	60	7.70	0	3050	73
623-1A (1)	1200	6.7	60	8.00	0	3460	72
624-1A (1)	1200	8.0	50	8.05	0	4010	69
625-1A (1)	1200	8.0	50	8.10	0	5020	70
626-1A (1)	1400	9.4	50	8.00	0	4790	70
627-1A (1)	1400	9.4	50	8.10	0	4390	74
629-1A (1)	1400	9.4	50	6.00	2441	3880	73
630-1A (1)	1400	9.4	50	7.05	2012	5570	90
631-1A (1)	700	9.4	25	7.00	2015	7430	66
632-1A	1400	9.4	50	7.00	2168	7100	82
633-1A	1400	6.7	70	7.05	2288	5000	93
634-1A (1)	1400	9.4	50	8.00	0	3630	68
635-1A (1)	1400	9.4	50	8.05	0	4600	67
636-1A (1)	1400	6.7	70	8.00	0	4300	78
637-1A (1)	1400	9.4	50	7.90	0	3330	62
638-1A (1)	1400	9.4	50	8.00	0	3690	71
639-1A (1)	1400	9.4	50	6.99	2120	3240	78
640-1A (1)	1400	9.4	50	7.05	1800	3650	75
642-1A	1050	9.4	37	6.97	2020	5740	68
VFG-1B (1)	1400	9.4	50	8.00	0	3800	61
VFG-1C (1)	1400	9.4	50	8.00	0	4300	59
VFG-1D (1)	1400	5.4	87	7.97	0	3800	88

(1) For these runs total inlet SO_2 concentrations and SO_2 removals were corrected for venturi SO_2 removal to give the estimated spray tower inlet SO_2 concentrations and SO_2 removals used in Equation 10-16.

The ranges of the operating variables are given below. Equation 14-16 should not be extrapolated beyond these ranges.

L/G	25-95 gal/Mcf
pH_i	6.0-9.0
$(Mg)_e$	0-2500 ppm
Cl	1000-13,000 ppm
v	5.4-9.4 ft/sec
$(SO_2)_i$	2000-4000 ppm

Four long-term runs (Runs 611-1A, 641-1A, 643-1A, and VFG-1A) at 2000 ppm effective dissolved magnesium ion concentration and low scrubber inlet liquor sulfate saturation (6 to 45 percent) were excluded from the correlation. The measured SO_2 removals were higher than those predicted by Equation 14-15 for saturated operation. SO_2 removal for low gypsum saturation operation with magnesium cannot be predicted at this time (see Subsection 14.2.2 for discussion).

Measured percent SO_2 removals and those predicted from Equation 14-16 are shown in Figure 14-20. Equation 14-16 accounts for 78 percent of the variation in the combined data (89 percent for the factorial data and 63 percent for the long-term data) with a standard error of estimate of 4.8 percent SO_2 removal (3.9 percent for the factorial data and 5.4 percent for the long-term data).

Figures 14-21 through 14-26 show parametric plots derived from Equation 14-16 and the corresponding Shawnee spray tower lime

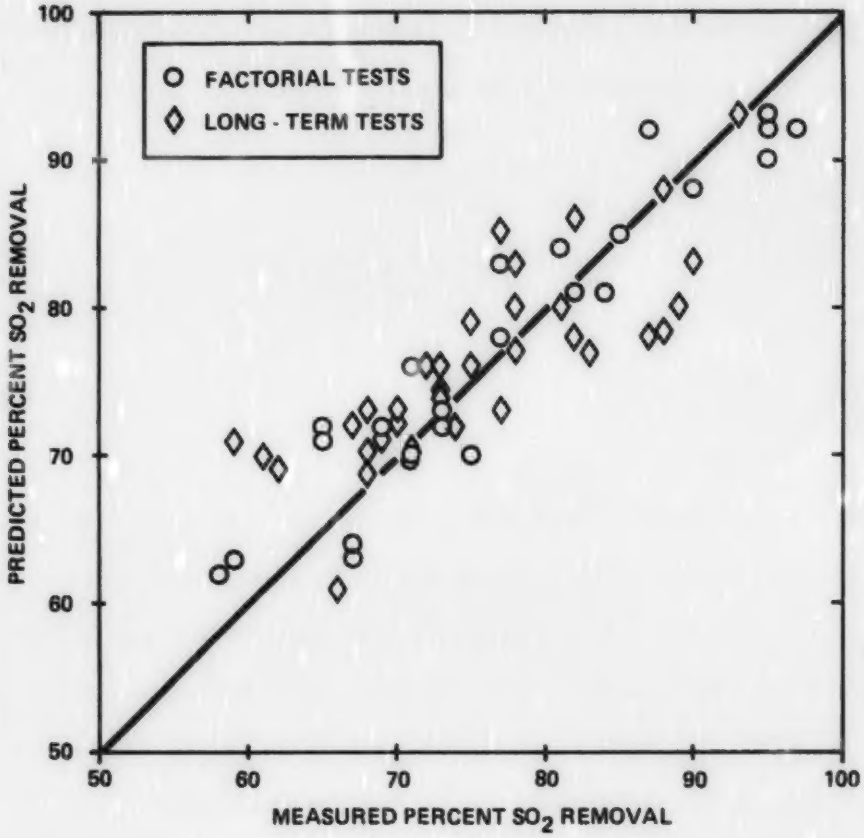


Figure 14-20. Comparison of Experimental Data and Predicted Values (Equation 14-16) of SO_2 Removal - Spray Tower with Lime

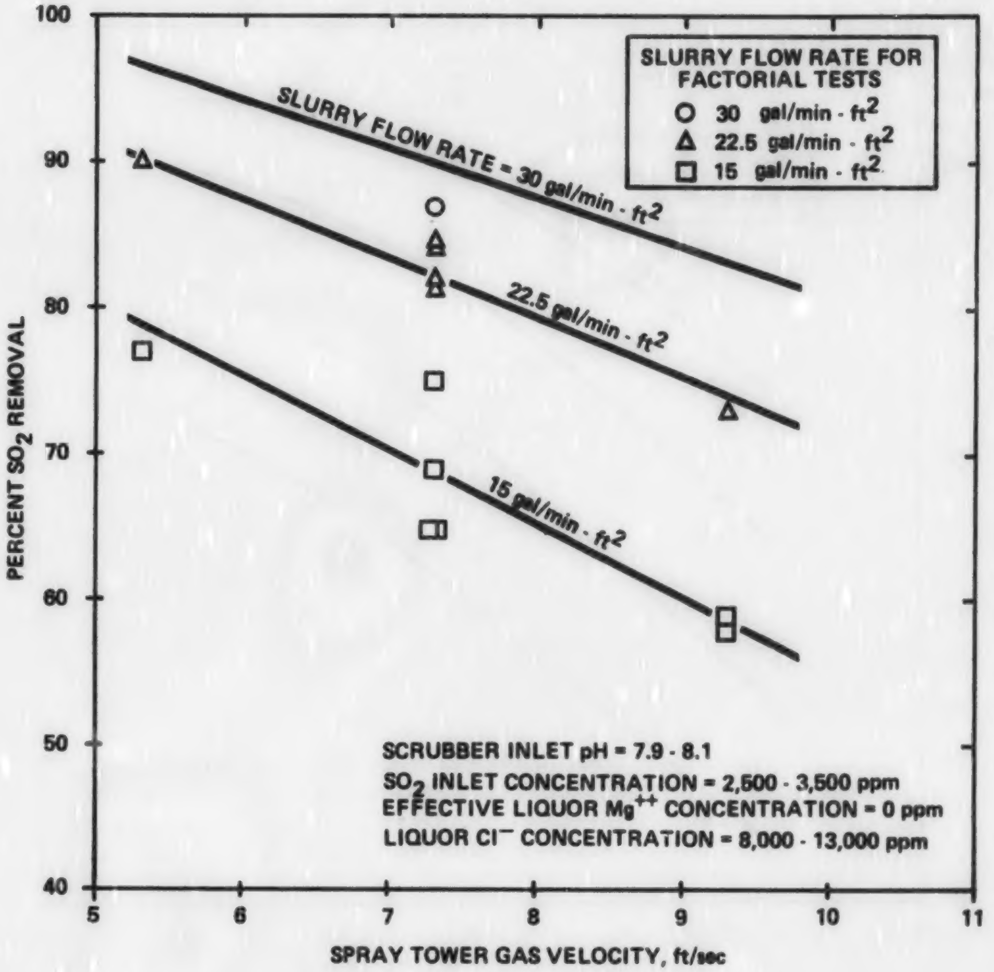


Figure 14-21. Gas Velocity and Slurry Flow Rate Versus Predicted (Equation 14-16) and Measured SO_2 Removal - Spray Tower with Lime

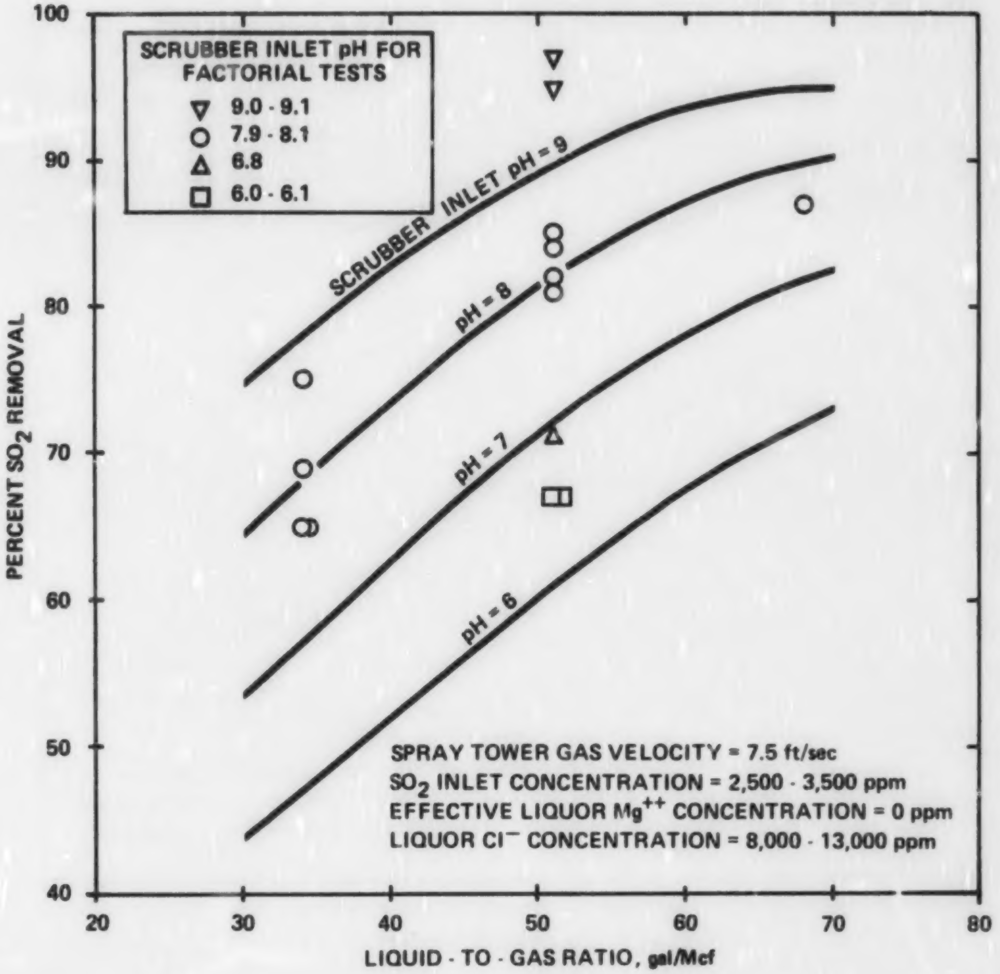


Figure 14-22. Liquid-to-Gas Ratio and Scrubber Inlet pH Versus Predicted (Equation 14-16) and Measured SO_2 Removal - Spray Tower with Lime

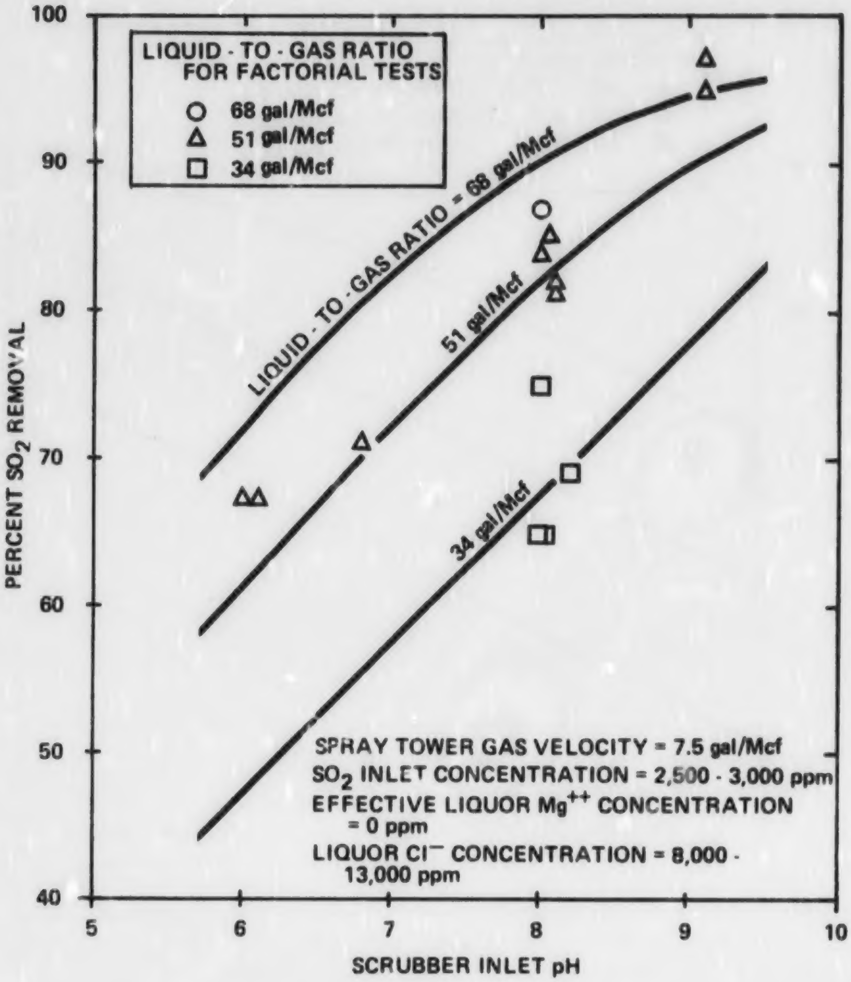


Figure 14-23. Scrubber Inlet pH and Liquid-to-Gas Ratio Versus Predicted (Equation 14-16) and Measured SO_2 Removal - Spray Tower with Lime

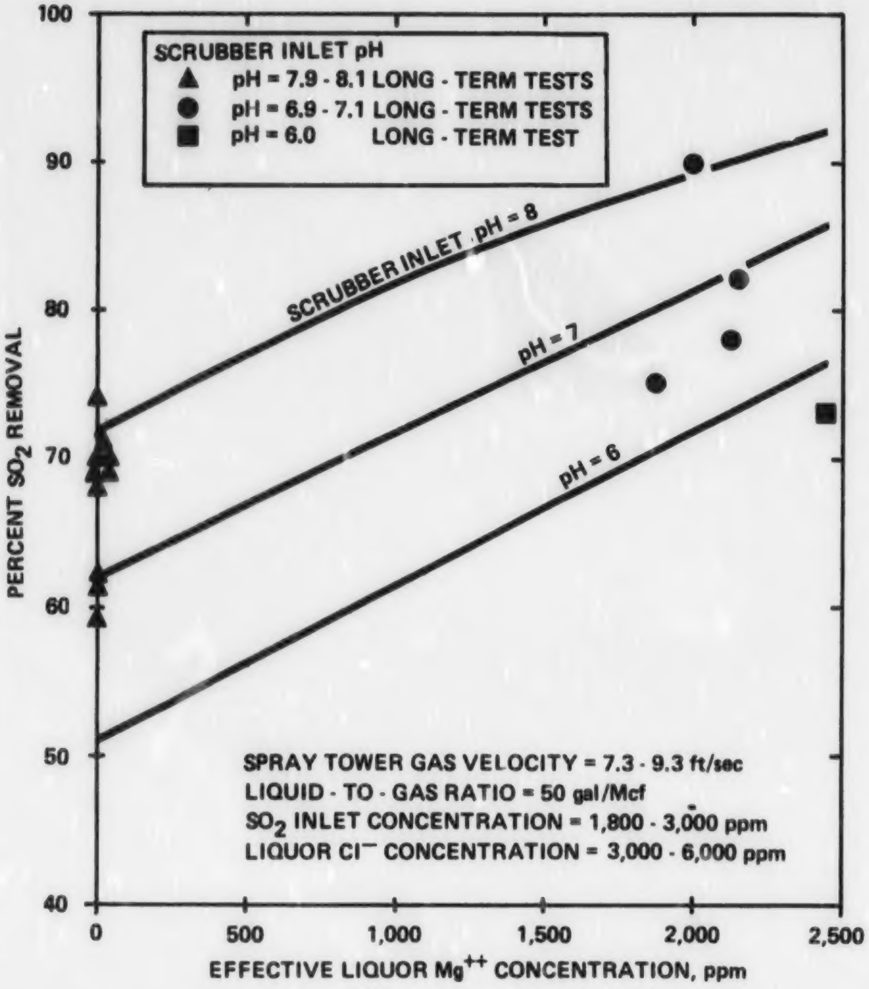


Figure 14-24. Effective Magnesium and Scrubber Inlet pH Versus Predicted (Equation 14-16) and Measured SO_2 Removal - Spray Tower with Lime

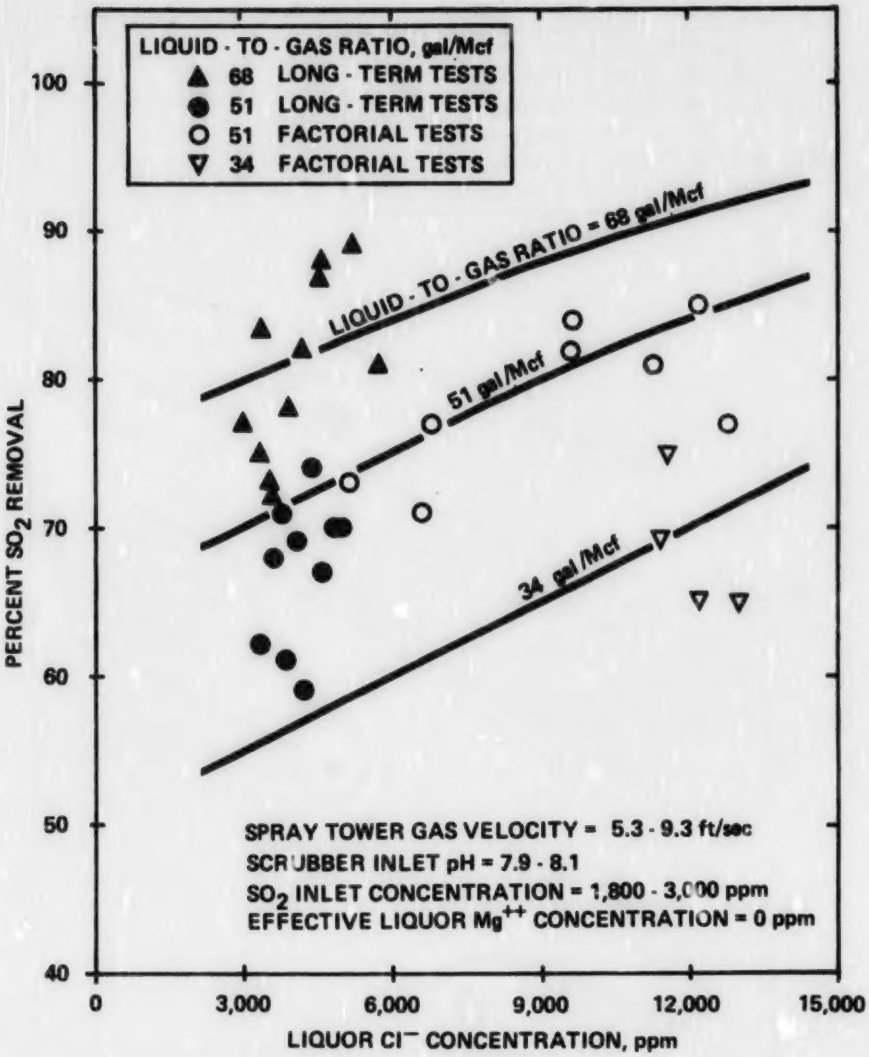


Figure 14-25. Chloride Concentration and Liquid-to-Gas Ratio Versus Predicted (Equation 14-16) and Measured SO_2 Removal - Spray Tower with Lime

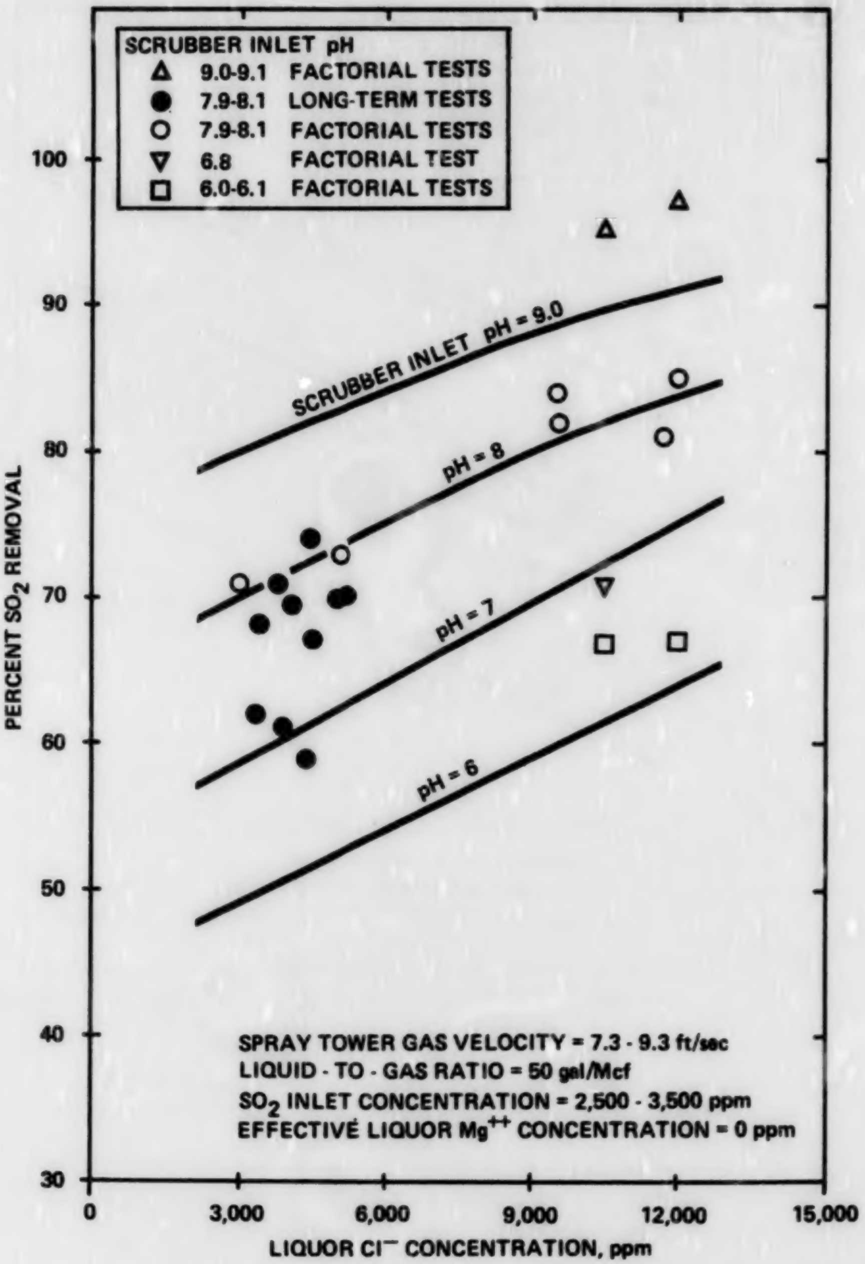


Figure 14-26. Chloride Concentration and Scrubber Inlet pH Versus Predicted (Equation 14-16) and Measured SO_2 Removal - Spray Tower with Lime

factorial run-averaged data.

A nomograph for prediction of SO_2 removal is discussed in Subsection 14.4 and presented as Figure 14-35. This nomograph is based upon Equation 14-16.

Correction of total system SO_2 removals to obtain spray tower removals (by elimination of venturi effects) is discussed in Subsection 14.2.3.

Insufficient data limited the fit of Equation 14-16 in several ways. The fitted runs had only two levels of effective magnesium ion concentration: zero and 2000 ppm. Additional data that include higher levels of magnesium would give a more accurate estimate of the effect of magnesium on SO_2 removal.

For lime scrubbing, there appears to be no theoretical basis for a variation in SO_2 removal with chloride ion concentration. However, the data show a strong correlation between these two variables. In the absence of a theoretically based variable with a more statistically significant effect on SO_2 removal, chloride ion concentration was used in Equation 14-16.

An additional drawback to Equation 14-16 is that no consistent effect of inlet SO_2 concentration on SO_2 removal could be obtained statistically, although such an effect is expected theoretically. Correlation of individual point values (rather than run-averaged values) of inlet SO_2 concentration with SO_2 removal indicated a very strong effect (about twice as strong as for limestone) for venturi/spray tower long-term runs, but no effect at all for spray tower long-term runs (minimum pressure drop across the venturi). Run-averaged values of inlet SO_2 concentration did not correlate with run-averaged values of SO_2 removal, but this might be attributed to the relatively narrow range of average inlet SO_2 concentrations (2500 to 3500 ppm at the venturi inlet and about 1800 to 3500 ppm at the spray tower inlet). Since attempts to include even a moderate effect of inlet SO_2 concentration in Equation 14-16 were statistically detrimental to the accuracy of prediction of SO_2 removal for the fitted runs, no effect of inlet SO_2 concentration was included in the equation.

14.3.2 TCA Equation for SO_2 Removal by Lime Slurry

The following equation for SO_2 removal has been fitted to the 37 TCA lime factorial runs made during 1976 (see Section 9) and to 16 TCA long-term runs (Runs 601-2A through 616-2A):

$$\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\left\{ - 0.0010\,(L/G)^{1.12}\,v^{0.65} \exp\left[0.18\,pH_i + 1.5 \times 10^{-4}\,(Mg)_e - 2.2 \times 10^{-4}(SO_2)_i + 0.0039v\left(\frac{h_{tot}}{d_s} + N_G\right)\right]\right\} \qquad (14\text{-}17)$$

where

d_s = diameter of the TCA sphere (1.5 inches at Shawnee)

h_{tot} = total height of spheres in TCA, inches

L/G = liquid-to-gas ratio in scrubber (125°F, humidified gas), gal/Mcf

$(Mg)_e$ = effective magnesium ion concentration, ppm
= [ppm Mg^{++} - (ppm $Cl^-/2.92$)] for $Mg^{++} > Cl^-/2.92$
= 0 for $Mg^{++} \leq Cl^-/2.92$
where 2.92 = ratio by weight of Cl^- to Mg^{++} in MgCl

N_G = number of grids or screens in the TCA (four at Shawnee)

pH_i = scrubber inlet liquor pH

$(SO_2)_i$ = inlet gas SO_2 concentration, ppm

v = gas velocity in scrubber (125°F, humidified gas), ft/sec

The run averaged values of the variables used in Equation 14-17 are tabulated in Table 14-4.

The ranges of the important operating variables for data used in Equation 14-17 are given below:

L/G	25-95 gal/Mcf
v	8.3-12.5 ft/sec
h_{tot}	0-22.5 inches
d_s	1.5 inch
N_G	4
pH_i	6.0-9.0
$(Mg)_e$	0-4000 ppm
$(SO_2)_i$	2200-3700 ppm
Cl	0-8000 ppm

Table 14-4

RUN-AVERAGED TCA RESULTS FOR LIME SCRUBBING TO WHICH EQUATION 14-17 WAS FITTED

Run Number	L/G, gal/Mcf	Gas Velocity, fps	Inlet pH	Effective Magnesium, ppm	Inlet SO_2 Conc., ppm	Total Height of Spheres, in.	SO_2 Removal, %
TCA-001	37	12.5	8.04	0	2497	15.0	74
TCA-002	37	8.3	8.10	0	2500	15.0	60
TCA-003	60	10.4	8.02	0	2431	15.0	86
TCA-004	45	10.4	8.13	0	2400	15.0	73
TCA-005	50	12.5	8.14	0	2512	15.0	92
TCA-006	75	8.3	8.22	0	2440	15.0	87
TCA-007	56	8.3	7.95	0	2257	15.0	73
TCA-008	30	10.4	8.12	0	2480	15.0	57
TCA-009	25	12.5	8.03	0	2771	15.0	54
TCA-010	50	12.5	8.02	0	2512	15.0	90
TCA-011	30	10.4	7.91	0	2550	22.5	59
TCA-012	60	10.4	7.93	0	2505	22.5	89
TCA-013	45	10.4	8.12	0	2520	22.5	74
TCA-014	60	10.4	8.13	0	2420	22.5	90
TCA-015	37	12.5	8.20	0	2543	0.0	54
TCA-016	37	8.3	8.06	0	2532	0.0	49
TCA-017	60	10.4	7.98	0	2417	0.0	70
TCA-018	45	10.4	8.00	0	2451	0.0	[illegible]
TCA-019	50	12.5	8.15	0	2420	0.0	[illegible]
TCA-020	75	8.3	7.99	0	2400	0.0	76
TCA-021	56	8.3	8.01	0	2503	0.0	66
TCA-022	30	10.4	8.08	0	2552	0.0	46
TCA-023	25	12.5	7.97	0	2474	0.0	43
TCA-024	50	12.5	7.99	0	2383	0.0	67
TCA-025	30	10.4	6.91	0	2787	15.0	53
TCA-026	60	10.4	9.07	0	2571	15.0	95
TCA-027	30	10.4	5.99	0	2707	15.0	49
TCA-028	30	10.4	8.06	0	2477	15.0	60
TCA-029	60	10.4	6.11	0	2423	15.0	74
TCA-030	30	10.4	9.01	0	2640	15.0	71
TCA-031	60	10.4	6.89	0	2605	15.0	79
TCA-032	60	10.4	6.06	0	2632	15.0	74
TCA-033	30	10.4	7.98	0	2640	15.0	58
TCA-034	60	10.4	6.03	0	2540	22.5	78
TCA-035	60	10.4	8.09	0	2345	15.0	85
TCA-036	60	10.4	5.97	0	2357	15.0	74
TCA-037	60	10.4	6.00	0	2604	15.0	74
601-2A	50	12.5	7.20	2222	2900	14.5	92
602-2A	50	12.5	7.00	2010	3150	14.5	88
603-2A	50	12.5	6.95	2138	3350	14.5	84
604-2A	37	12.5	6.90	2092	3200	14.0	73
605-2A	73	8.5	7.00	2137	3500	14.0	80
606-2A	37	12.5	8.00	2060	3300	14.0	76
607-2A	37	12.5	7.95	4073	3200	13.5	86
608-2A	37	12.5	7.93	4026	3550	13.5	82
609-2A	37	12.5	6.97	2035	3050	13.5	74
610-2A	37	12.5	7.96	2175	2925	13.0	84
611-2A	37	12.5	7.96	2094	2900	12.5	81
612-2A	37	12.5	7.96	2137	3050	12.5	81
613-2A	50	12.5	6.88	2198	3050	12.0	84
614-2A	37	12.5	8.06	2023	3650	12.0	75
615-2A	50	12.5	7.10	2225	3200	11.5	87
616-2A	50	12.5	8.05	0	3300	11.0	72

Equation 14-17 should not be used outside these ranges.

Long-term Run 608-2B, made at 4000 ppm effective magnesium ion concentration and low scrubber inlet liquor gypsum saturation (11 percent), was excluded from the correlation because the measured SO_2 removal was high relative to removals obtained during saturated operation. SO_2 removal by liquor containing magnesium and at low gypsum saturation cannot be predicted at this time (see Subsection 14.2.2).

Meaured SO_2 removals are plotted against those predicted from Equation 14-17 in Figure 14-27. Equation 14-17 accounts for 94 percent of the variation in the combined data (94 percent for the factorial data and 81 percent for the long-term data), with a standard error of estimate of 3.3 percent SO_2 removal (3.6 percent for the factorial data and 2.7 percent for the long-term data).

Figures 14-28 through 14-32 are parametric plots derived from Equation 14-17. These figures show corresponding Shawnee TCA lime run-averaged data.

A nomograph for prediction of SO_2 removal is discussed in Subsection 14.4 and presented as Figure 14-36. The nomograph is based on Equation 14-17.

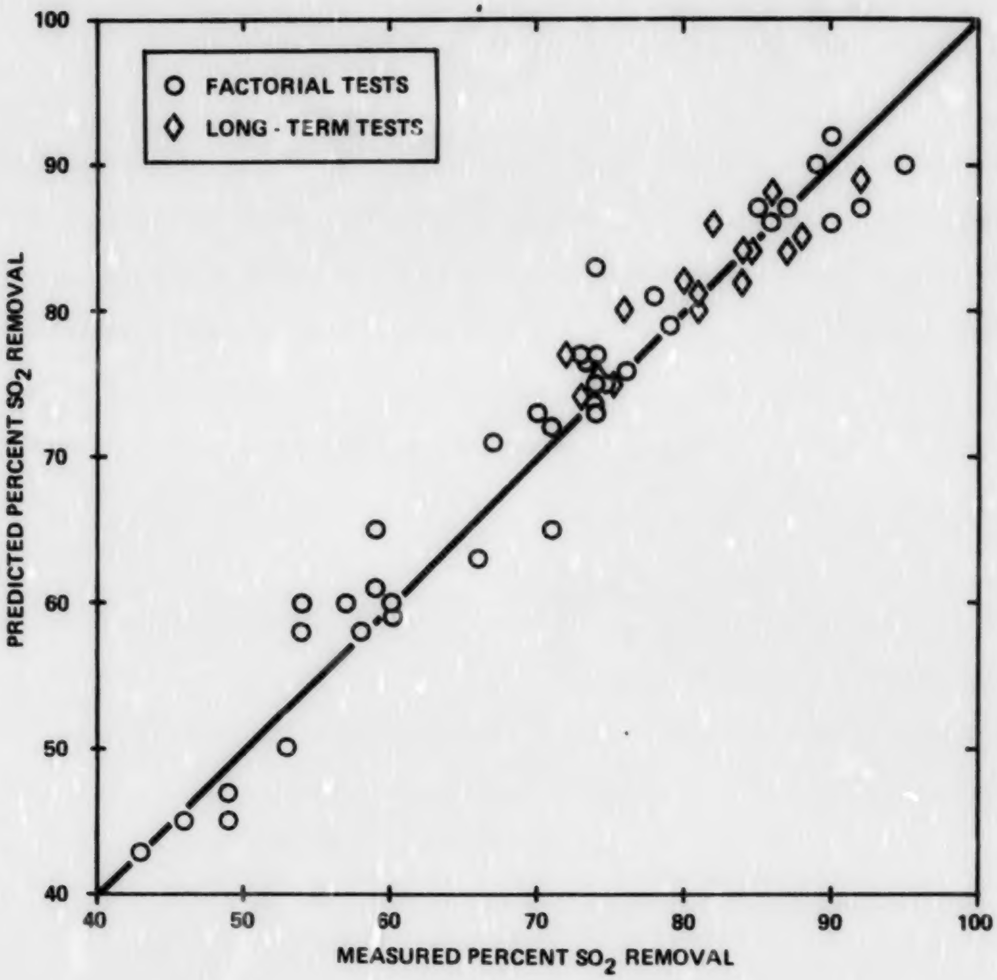


Figure 14-27. Comparison of Experimental Data and Predicted Values (Equation 14-17) of SO_2 Removal - TCA with Lime

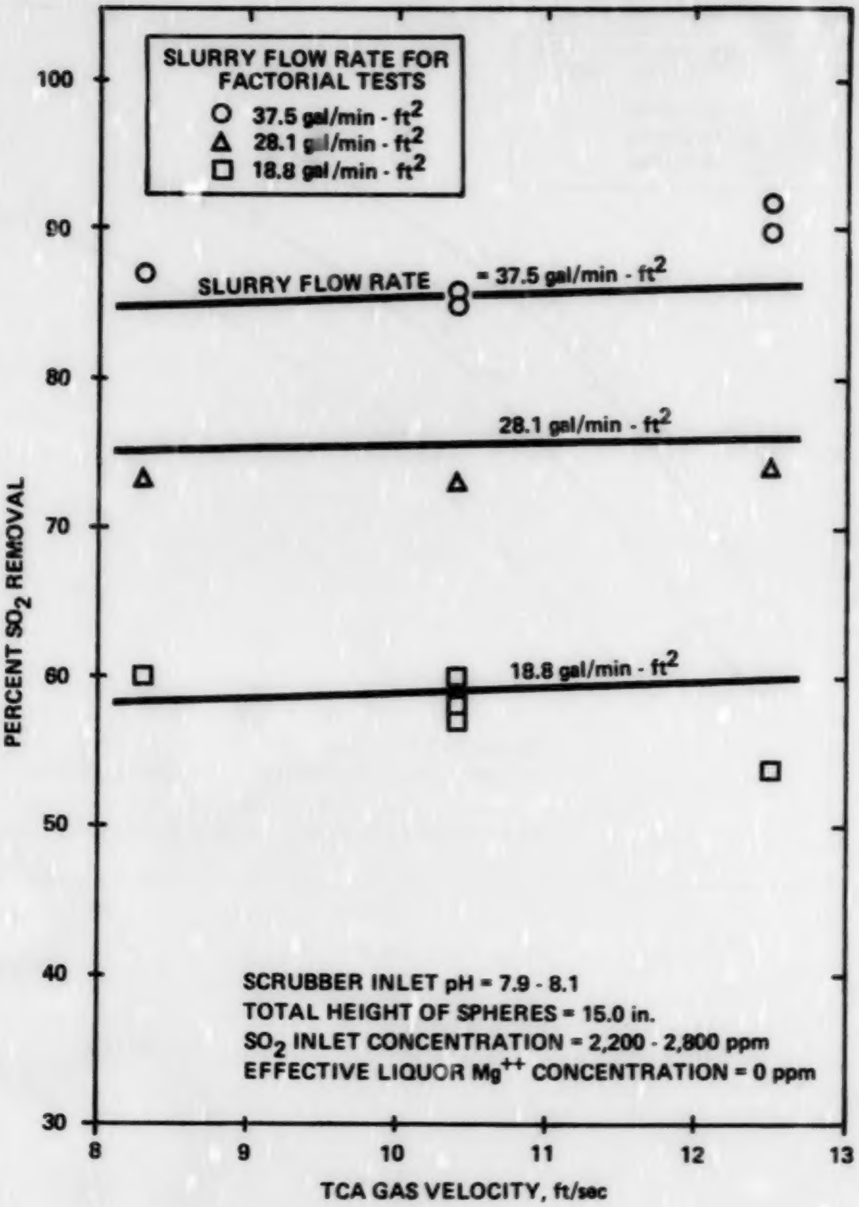


Figure 14-28. TCA Gas Velocity and Slurry Flow Rate Versus Predicted (Equation 14-17) and Measured SO_2 Removal - TCA with Lime

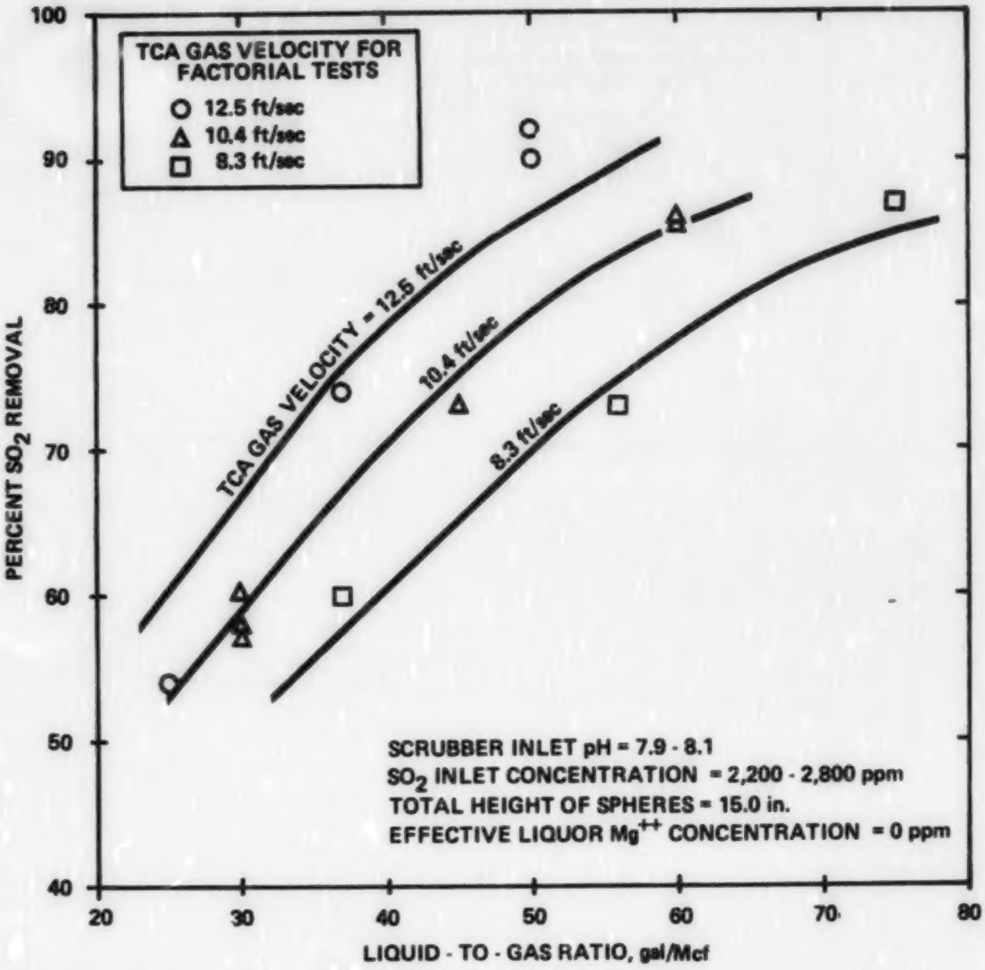


Figure 14-29. Liquid-to-Gas Ratio and Scrubber Gas Velocity Versus Predicted (Equation 14-17) and Measured SO_2 Removal - TCA with Lime

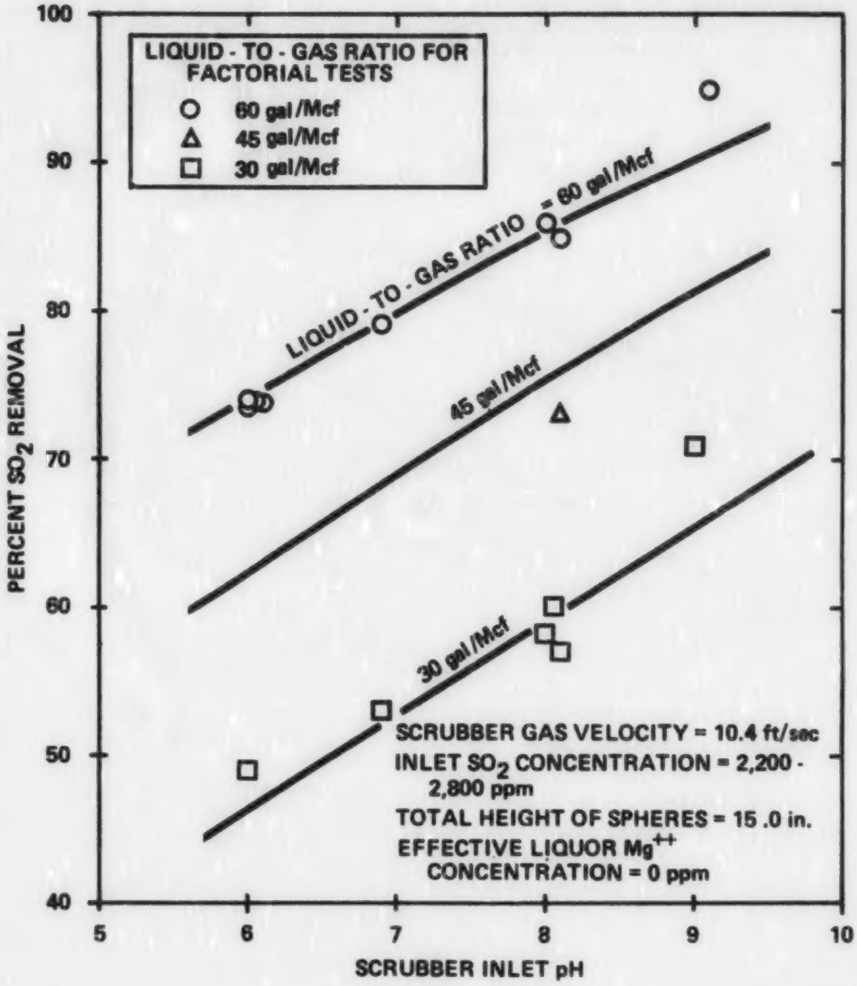


Figure 14-30. Scrubber Inlet pH and Liquid-to-Gas Ratio Versus Predicted (Equation 14-17) and Measured SO_2 Removal - TCA with Lime

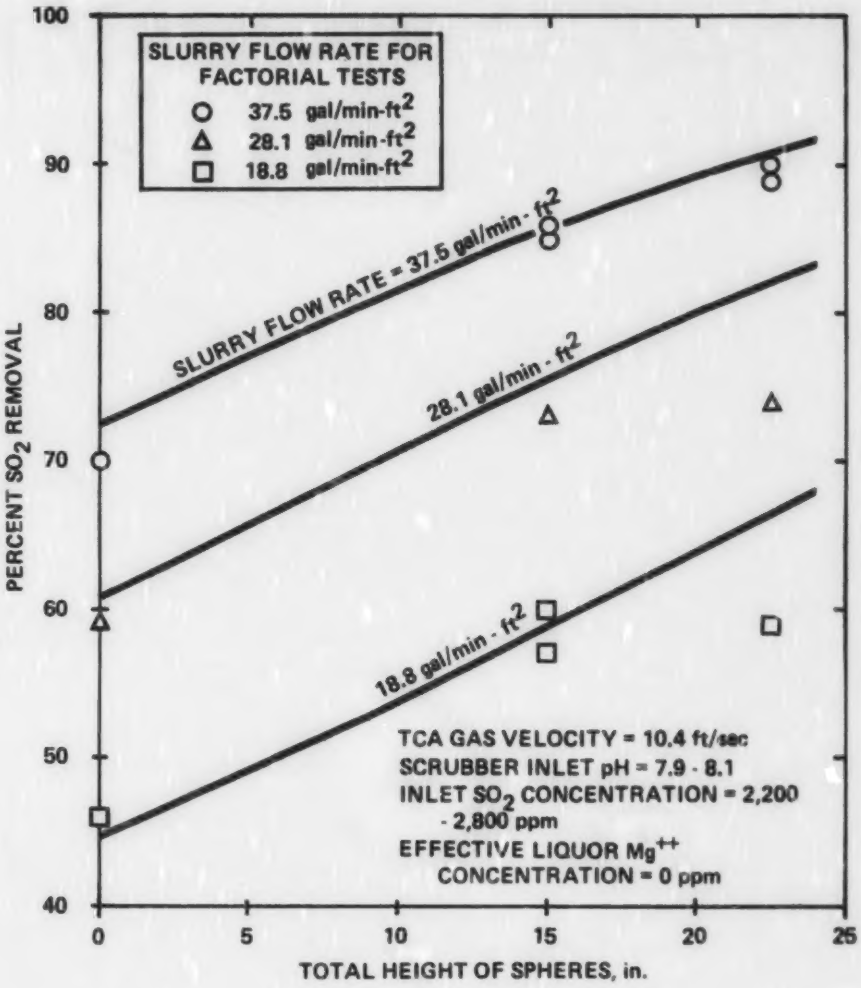


Figure 14-31. Total Height of Spheres and Slurry Flow Rate Versus Predicted (Equation 14-17) and Measured SO2 Removal - TCA with Lime

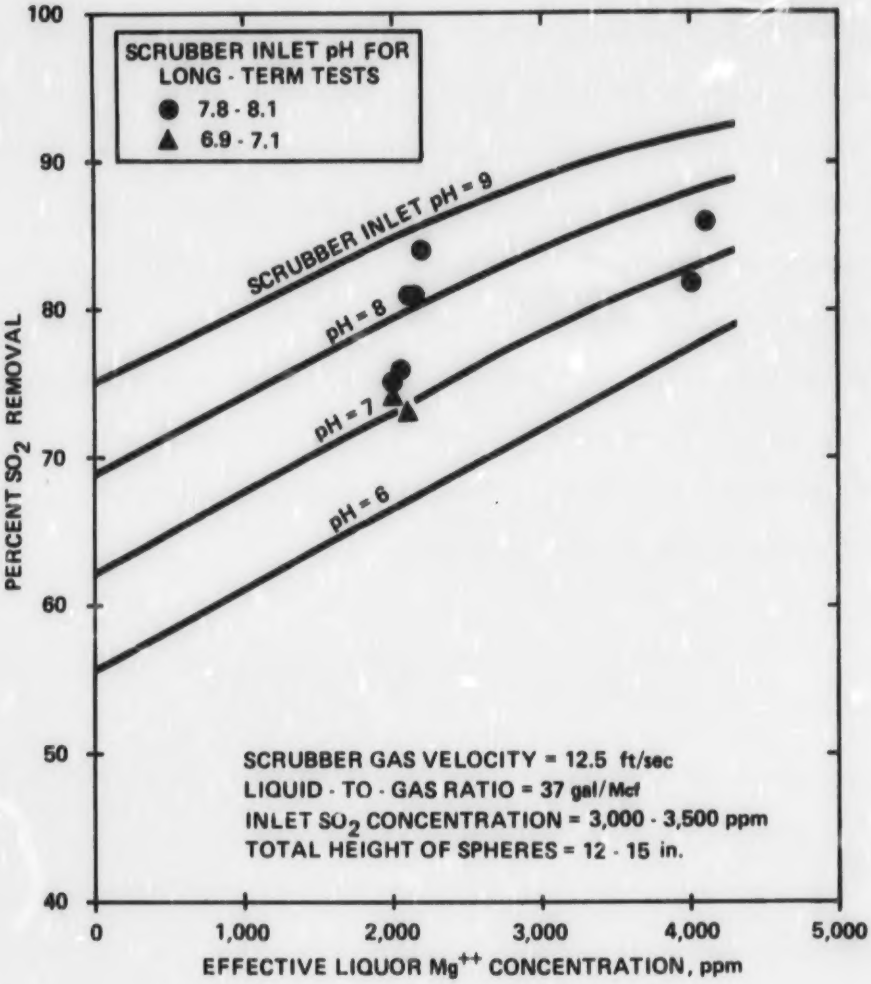


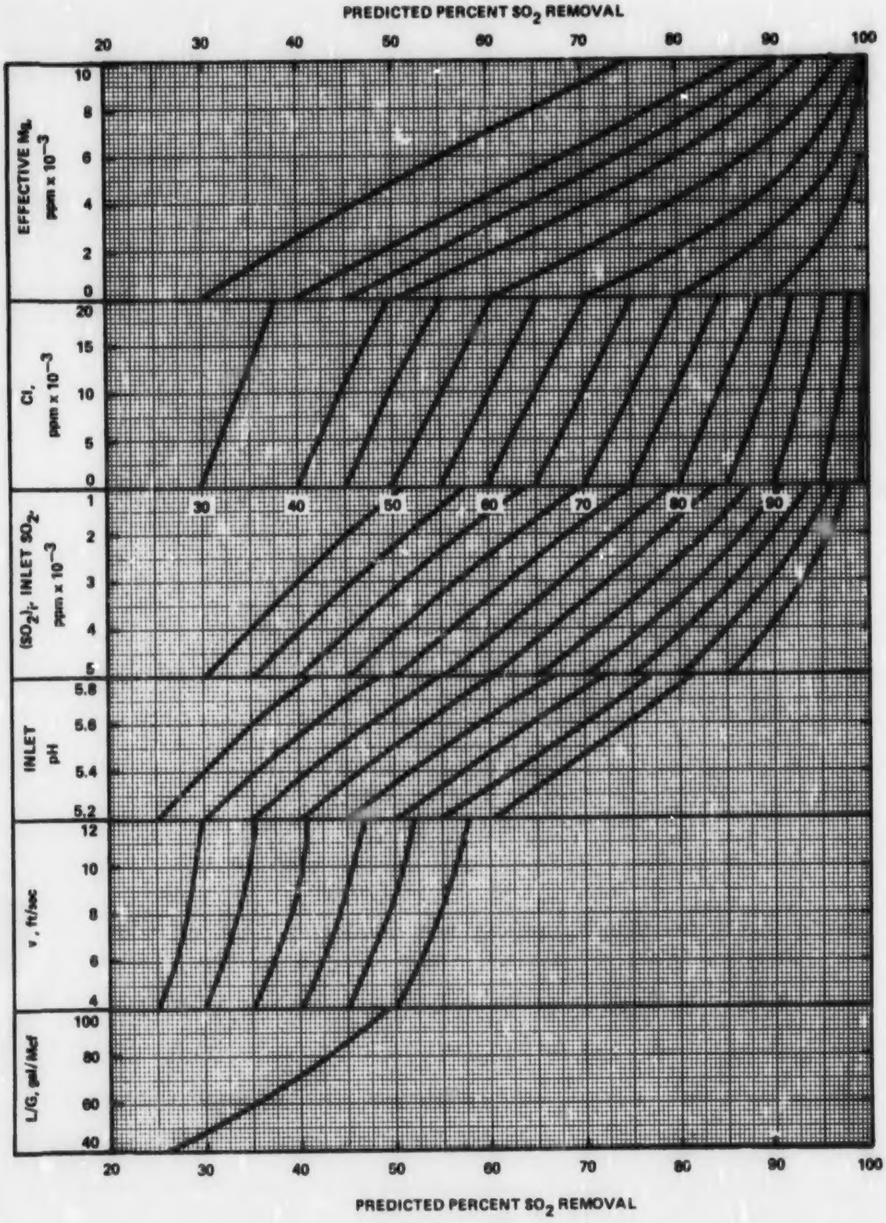
Figure 14-32. Effective Magnesium and Scrubber Inlet pH Versus Predicted (Equation 14-17) and Measured SO_2 Removal - TCA with Lime

Magnesium ion concentration, inlet SO_2 concentration, and chloride ion concentration are roughly at one level for the factorial runs and another level for the long-term runs. Differences in the two sets of runs can be caused by any or all of the three variables. Thus, the individual effects of each variable on SO_2 removal are hard to distinguish. Equation 14-17 was the best fit and is statistically valid for the data used. New runs might show some chloride effect, and the effects of inlet SO_2 concentration and magnesium might be different from those indicated in the equation. Therefore, Equation 14-17 should be used with caution.

14.4 NOMOGRAPHS FOR SO_2 REMOVAL BY LIMESTONE AND LIME WET SCRUBBING

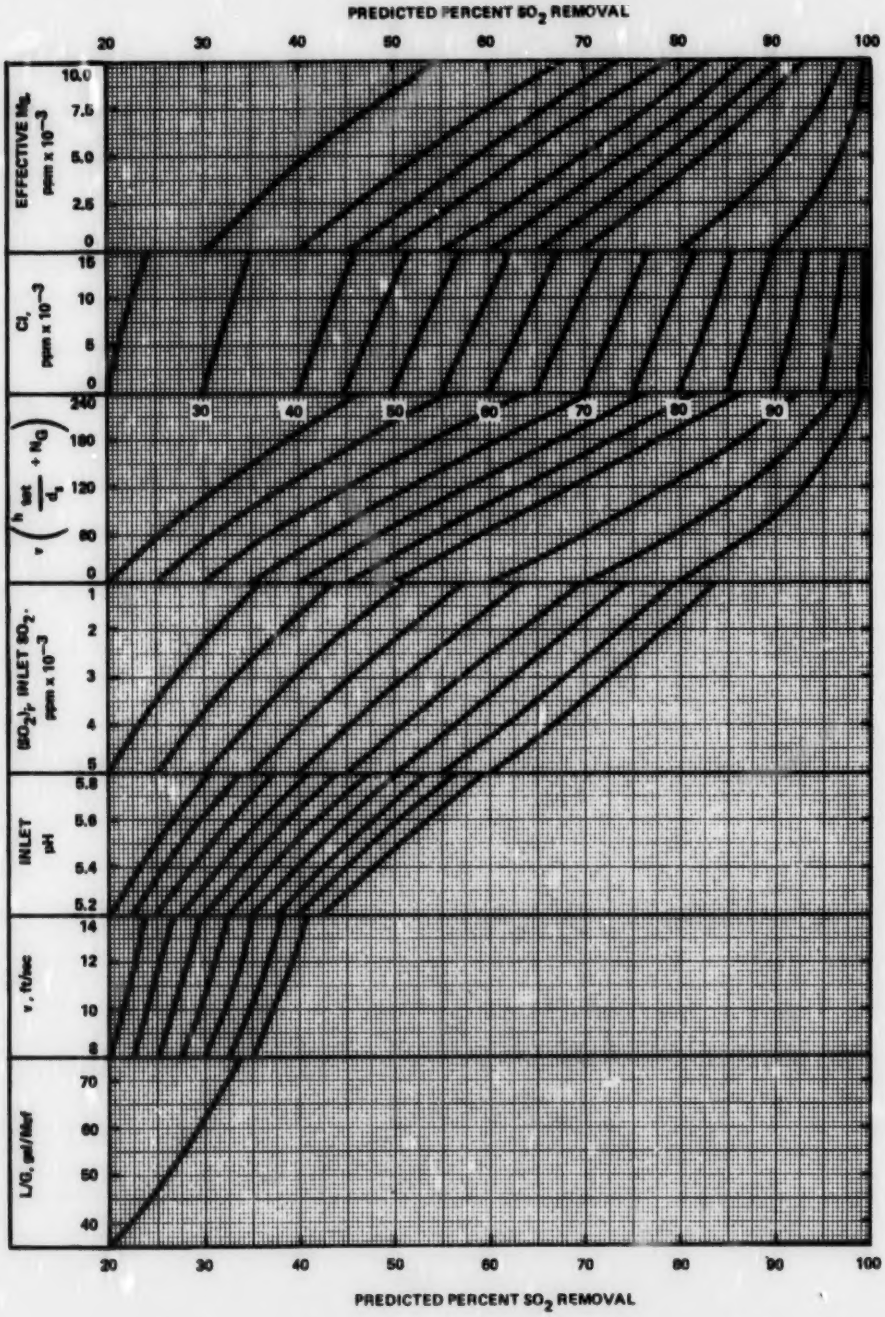
Figures 14-33 through 14-36 are nomographs for the prediction, from operating variables, of SO_2 removal by limestone or lime wet-scrubbing with a spray tower or a TCA. Nomographs for limestone scrubbing with a spray tower and a TCA are shown in Figures 14-33 and 14-34, respectively, and are derived from Equations 14-14 and 14-15. Figures 14-35 and 14-36 for lime scrubbing with a spray tower and a TCA are derived from Equations 14-16 and 14-17. The nomographs cover the same ranges of operation as the corresponding equations.

In practice, a prediction of SO_2 removal made by use of the nomo-



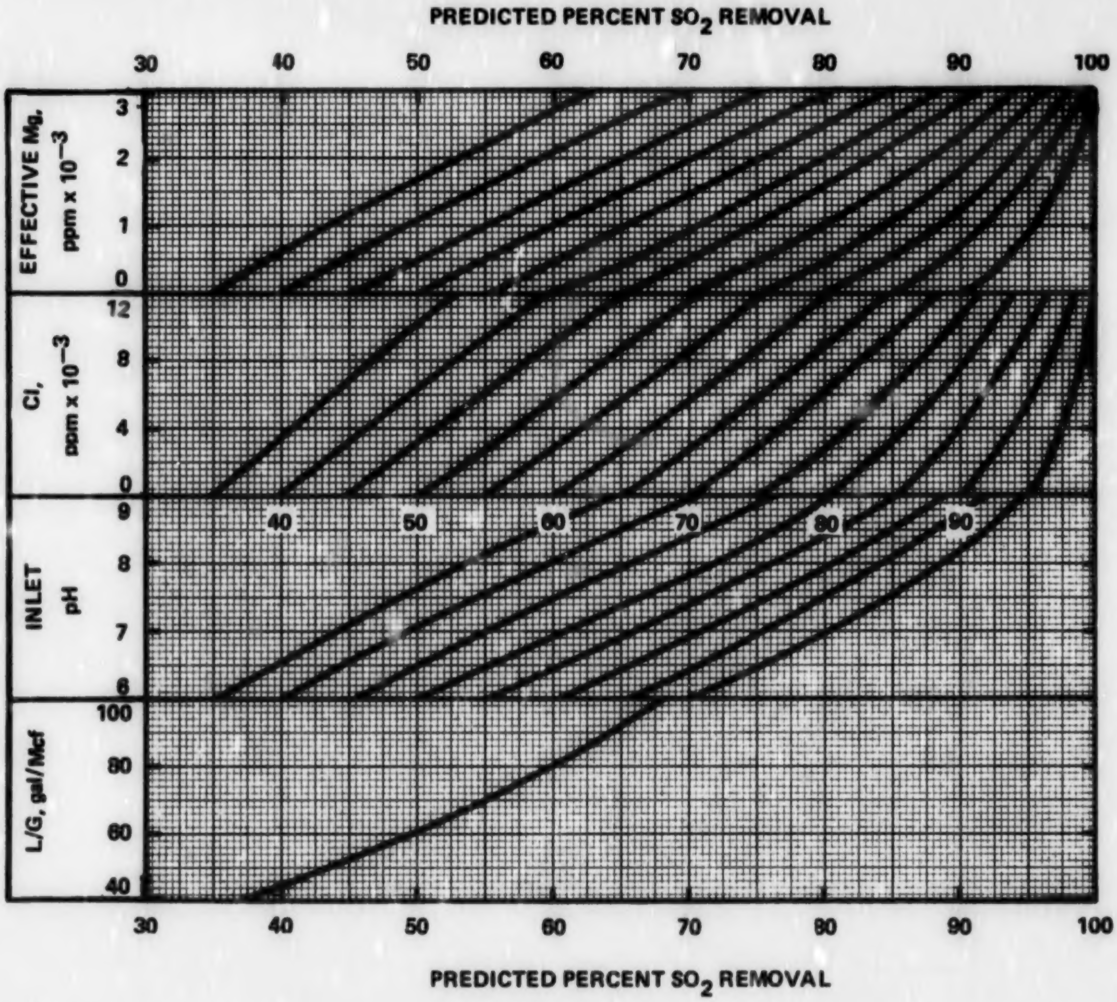
$$\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\left\{-9.8 \times 10^{-5}(L/G)^{0.92} v^{0.19} \exp\left[pH_i + 1.35 \times 10^{-4}(Mg)_e - 1.7 \times 10^{-4}(SO_2)_i + 1.45 \times 10^{-5} Cl\right]\right\}$$

Figure 14-33. Nomograph for Percent SO_2 Removal by Limestone Scrubbing in a Spray Tower



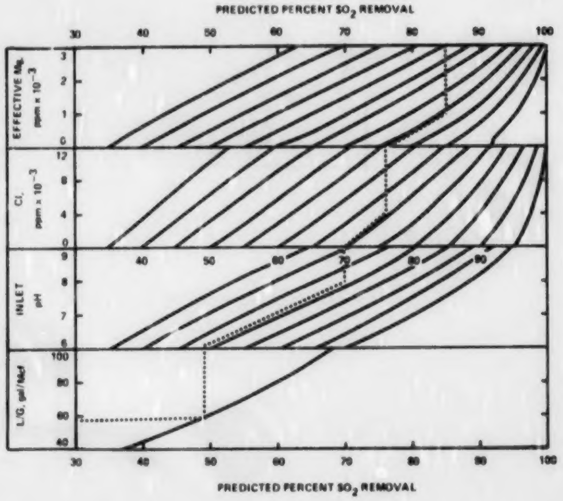
$$\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\left(-2.05 \times 10^{-4}\,(L/G)^{0.81}\,v^{0.36}\,\exp\left[4.3 \times 10^{-3}\,v\left(\frac{h_{tot}}{d_s} + N_G\right) + 0.81\,pH_i + 7.9 \times 10^{-5}\,(Mg)_e - 1.7 \times 10^{-4}\,(SO_2)_i + 1.3 \times 10^{-5}\,Cl\right]\right)$$

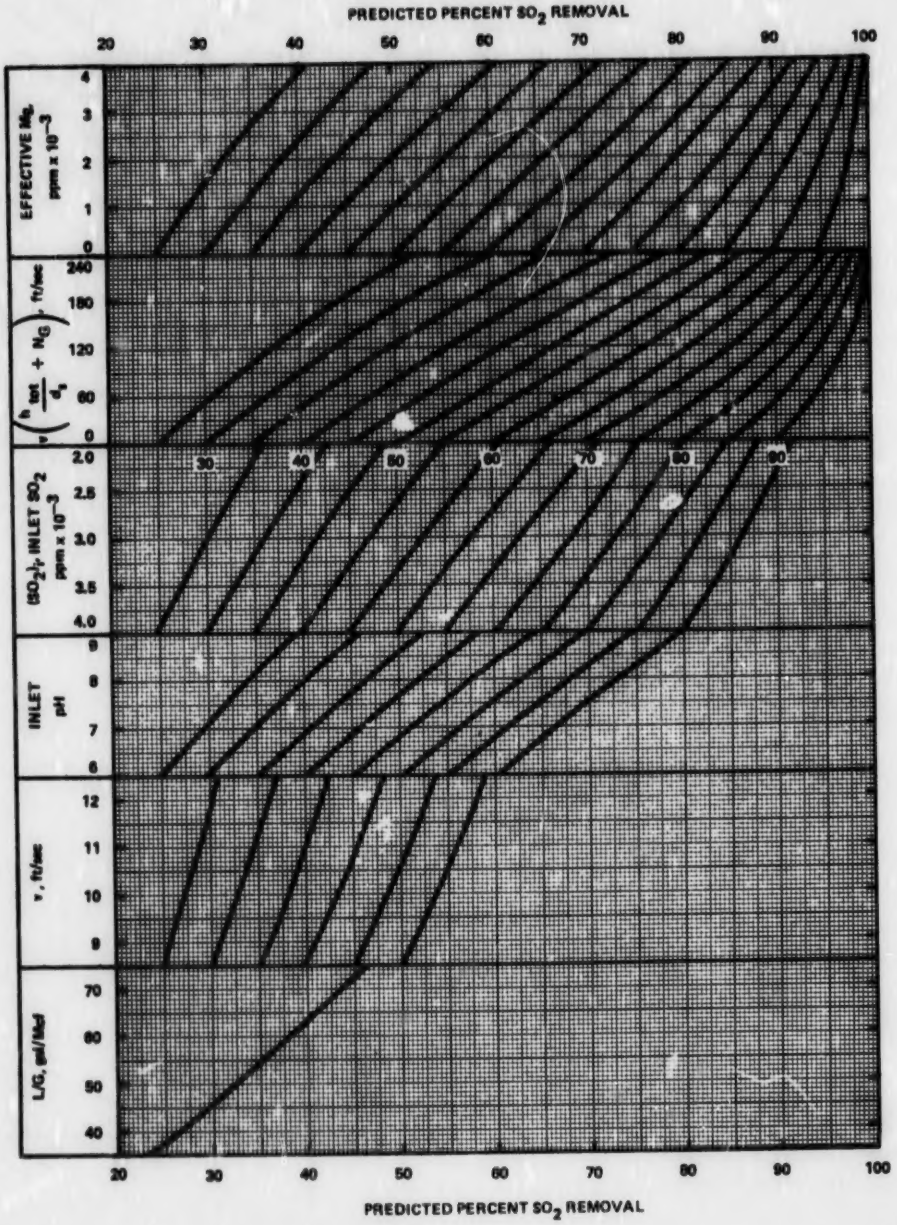
Figure 14-34. Nomograph for Percent SO_2 Removal by Limestone Scrubbing in a TCA



$$\text{Fraction SO}_2\text{ Removal} = 1 - \exp\left\{-0.0020\,(L/G)\exp\left[\,0.29\,\text{pH}_i + 2.8 \times 10^{-4}\,(\text{Mg})_e + 4.7 \times 10^{-5}\,\text{Cl}\right]\right\}$$

Figure 14-35. Nomograph for Percent SO_2 Removal by Lime Scrubbing in a Spray Tower





$$\text{Fraction } SO_2 \text{ Removal} = 1 - \exp\left\{-0.0010\,(L/G)^{1.12}v^{0.65}\exp\left[0.18\,pH_i + 1.5 \times 10^{-4}(Mg)_e - 2.2 \times 10^{-4}(SO_2)_i + 0.0039v\left(\frac{h_{tot}}{d_s} + N_G\right)\right]\right\}$$

Figure 14-36. Nomograph for Percent SO_2 Removal by Lime Scrubbing in a TCA

graphs is typically within about 1/2 percent of the corresponding equation prediction. The speed of calculation using the nomographs is about the same as for solving the corresponding equation by electronic calculator.

The inset in Figure 14-35 illustrates how these nomographs are used. First, the liquid-to-gas ratio is located on the bottommost curve. Then a vertical line is drawn to intersect with the next lowest horizontal line, which represents the lowest level of the next variable, scrubber inlet liquor pH. A line is then drawn upward from the horizontal line and parallel to the nearest pH curve, until the y-axis level corresponding to the specified pH, 8.0, is reached. Again, a vertical line is drawn to the horizontal line for the next operating variable, chloride ion concentration. This procedure is continued until the top of the nomograph is reached. The predicted SO_2 removal is then the x-axis value at this point. In the example case, the SO_2 removal predicted by the nomograph in Figure 12-35 is 85 percent; Equation 14-16 predicts 86 percent.

If SO_2 removal is specified in a design and prediction of another operating variable is required (e.g., scrubber inlet liquor pH), this prediction can be made from the nomograph by working upwards from the bottom of the nomograph and downwards from the top. The two resultant intersecting lines, one parallel to the nomograph pH curves from the bottom up and the other vertical from the top of the pH scale, meet at the y-axis value of the operating pH.

Section 15

LABORATORY QUALITY ASSURANCE PROGRAM

Laboratory quality assurance efforts at the Shawnee Test Facility continued with emphasis on evaluating and improving the analytical methods.

15.1 QUALITY ASSURANCE METHODS

The primary method for maintaining reliability of analytical data is a daily evaluation of analytical results by onsite and San Francisco personnel. Ionic imbalance and the general reasonableness of results are used as the measure of acceptability. Solids analyses with an ionic imbalance greater than ± 8.5 percent and liquor analyses with an ionic imbalance greater than ± 15 percent (± 20 percent prior to August 18, 1976) are rejected. The solids ionic imbalance limit of ± 8.5 percent was based on the results of about 300 solids analyses performed prior to December 12, 1975. In these analyses, the average ionic imbalance was ± 3.5 percent, with a standard deviation of 2.5 percent. Thus, ±8.5 percent ionic imbalance includes approximately 95 percent of the solids analysis results. The corresponding liquor ionic imbalance values for 60 analyses performed in July 1976 had an average of ± 6.4 percent and a standard deviation of 4.4 percent. Thus, ± 15 percent ionic imbalance includes 95 percent of the liquor analysis results.

The results of the analysis of liquor and solids standards are used to monitor both the accuracy (closeness between the true and the experimental determined values) and the precision (reproducibility) of analytical results. In addition, a TVA program for interlaboratory comparison of analytical results was initiated during this reporting period. Selected quality assurance samples are now routinely sent to the TVA General Analytical Laboratory in Muscle Shoals after analysis at the Shawnee Test Facility laboratory.

Primary analytical data are tabulated in the Shawnee Test Program database. A system has been established for entering flags to mark questionable analytical results in the database. Flagged data then can be easily excluded from calculations. Flags are also used to mark valid analytical results from samples obtained during line-out and non-representative operational periods. See Appendix D for details of the flagging system.

15.2 STOICHIOMETRIC RATIO CALCULATION

The stoichiometric ratio of moles of calcium added per mole of SO_2 absorbed has been calculated in the past as the mole ratio of total calcium to the total sulfur in the slurry solids. Total calcium (as weight percent of CaO) and total sulfur (as weight percent of SO_3) were routinely measured in the solids using a Siemens X-ray fluorescence spectrometer (Methods 15, 16, and 17, Reference 7). The stoichiometric ratio, designated as SR, was then calculated from the following equation:

$$\text{SR} = \frac{\text{percent CaO}}{\text{percent SO}_3} \times \frac{80.06}{56.08}$$

This equation for calculating stoichiometric ratio has been replaced by a more accurate expression, designated as $SRCO_3$, and calculated from the following equation:

$$\text{SRCO}_3 = 1 + \frac{\text{percent CO}_2}{\text{percent SO}_3} \times \frac{80.06}{44.00}$$

where percent CO_2 is the carbonate (as weight percent of CO_2) in the slurry solids, measured by the CO_2 evolution method (Method 5, Reference 7); and percent SO_3 is the total sulfur (as weight percent of SO_3) in the solids, measured by X-ray fluorescence.

$SRCO_3$ is considered to be a more accurate indicator of stoichiometric ratio than SR for the following reasons:

- Simple error analysis shows that $SRCO_3$ is less subject to the effects of random error than SR, especially at low stoichiometric ratios
- $SRCO_3$ is less subject to consistent bias than SR because the results from two entirely different analytical methods are used to calculate the $SRCO_3$ values. The X-ray fluorescence methods used to obtain SR values are subject to the possibility of consistent error (bias) in the analytical results

Both SR and $SRCO_3$ are calculated from data obtained from analysis of the scrubber slurry solids. The slurry liquor sulfur content is negligible for runs without MgO addition and therefore does not affect the stoichiometric ratio. However, when MgO is added to the scrubber slurry, some sulfur compounds are dissolved in the liquor and a portion of this sulfur leaves the system in the liquor associated with the solids that are removed. The stoichiometric ratio error can be as high as 20 percent if sulfur in the liquor is ignored for runs where MgO is used.

Stoichiometric ratios given in this report and in the database have not been corrected for this factor yet, but a rough correction has been applied to the stoichiometric ratios reported in summary tables and data plots. The feasibility of correcting stoichiometric ratios recorded in the database is currently being investigated.

15.3 EVALUATION AND MODIFICATION OF ANALYTICAL PROCEDURES

Analytical methodology has been subject to continual review through evaluation of precision and accuracy data, reasonableness of results, and reliability records. On the basis of such reviews, the following analytical procedures were judged to require improvements:

- Measurement of pH in slurries
- Determination of calcium and total sulfur in solids by X-ray fluorescence
- Determination of sulfite in solids and liquors by titration
- Determination of total sulfur in solids and liquors by titration
- Measurement of carbonate in solids by CO_2 evolution
- Measurement of calcium and magnesium ions in liquors by atomic absorption when these ions are present in high concentration

These procedures are described in the Shawnee Chemical Procedures Laboratory Manual (Reference 7).

The modifications and alternatives investigated for these analytical procedures are summarized below.

15.3.1 pH in Slurries

Measurement of pH in slurry liquor at the Shawnee Test Facility has been subject to frequent unexplained pH excursions, and there has been a high rate of pH electrode failure. This situation was tolerable during runs lasting many days but became unacceptable when the short-term factorial tests were begun in February 1976. These tests required changing the run conditions every 6 to 8 hours and controlling slurry liquor pH ± 0.1 pH unit.

A study of the pH measurement procedure was initiated at the Shawnee test site in November 1975 and concluded in March 1976.

It was found that variability of laboratory pH data in the past was due primarily to thermal cycling (cold buffer to hot slurry) of the electrodes and to fouling of the reference electrode junction by slurry solids. An analysis of the problem produced a number of recommendations for improved quality control, all of which have been implemented.

Laboratory-prepared buffers are no longer used at the facility; certified buffers with known temperature dependence are used for buffering of all glass electrodes. More importantly, off-line electrodes are being stored at pH 4 in hot solutions saturated with potassium chloride (KCl). This method of storing electrodes between service periods has three important functions:

- The hot (50°C) solution minimizes thermal stress by holding the electrodes at a constant temperature while on-line or off-line. Repeated cycles of heating and cooling have been eliminated

- The saturated solution of KCl should increase life expectancy of the electrodes by preventing reference cell dilution
- The low pH (pH 4) of the solution reduces reference junction fouling by preventing buildup of acid-soluble solids on the cell surfaces during storage. It also keeps the glass membrane sensitized

The slurry liquor pH reading procedure has been improved by using two electrodes (one for each scrubber system), switching the electrodes at the beginning of each 8-hour shift, allowing a constant 4 minutes per reading whether in the slurry or in the buffer, and renewing the buffer solution at the beginning of each day shift.

In addition, a fully enclosed, heated and air conditioned field laboratory was constructed to facilitate sampling. A new pH meter (Fisher Model 520) with digital readout (to 0.001 pH unit) has been used in the field laboratory since March 1, 1976.

Electrodes with rubber-stopper connnections are no longer in use at Shawnee. Uniloc and Broadley-James combination electrodes, both with glass-to-glass seals, have been in use since March 1976 and are performing well. Quality control criteria call for an electrode to be discarded either if it cannot be zeroed at the correct buffer pH with the pH meter controls, or if it does not agree (within 0.2 pH unit in a slurry sample) with two "lab-standard" (i.e., new) electrodes used for reference purposes. In addition, onsite personnel are instructed to investigate the discrepancy if the laboratory and on-line pH values disagree by more than 0.2 pH unit for more than 2 hours.

An inventory control log documenting the work record of each electrode is being kept. In addition, the pH meters are checked every 2 months with a pH simulator.

The improved procedures outlined above have been in practice at Shawnee since March 1976 with very good results. Electrode life is now measured in months instead of weeks, and virtually no problems or inexplicable pH variations have been encountered since that time.

A detailed report covering the tests, recommendations, and subsequent results of the use of the improved procedures was issued in September 1976 (pH Study at Shawnee Test Facility -Phase II).*

15.3.2 Calcium and Total Sulfur Analyses in Solids

X-ray fluorescence spectrometry is the primary technique for performing calcium and total sulfur analyses in solids at the Shawnee

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* This report can be obtained from Bechtel Corporation.

Test Facility. It was found, however, that the original method (Method 16, Reference 7), as determined by quality control analyses of spiked slurry samples was subject to interference from the fly ash in the slurry solids.

The analytical procedure in the original method is summarized as follows:

- Dry the solids sample
- Form a pellet with the dried sample
- Subject the pellet to X-rays
- Take three successive counts of the characteristic X-rays emitted by calcium and sulfur
- Calculate the concentration by comparing sample X-ray intensities with the corresponding slurry solids standard X-ray intensities

Inaccuracies of this analysis were suspected to be the result of matrix interferences and particle size effects. Matrix interference is caused by absorption or emission of characteristic X-rays by the other elements. Particle size effects occur because characteristic X-ray emission depends to a varying extent on sample particle size.

Both of these effects can often be attenuated by diluting the sample with a substance that does not significantly absorb or emit X-rays during the analysis. Therefore, a new procedure (Method 17, Reference 7) was initiated in February 1976 which calls for the dilution

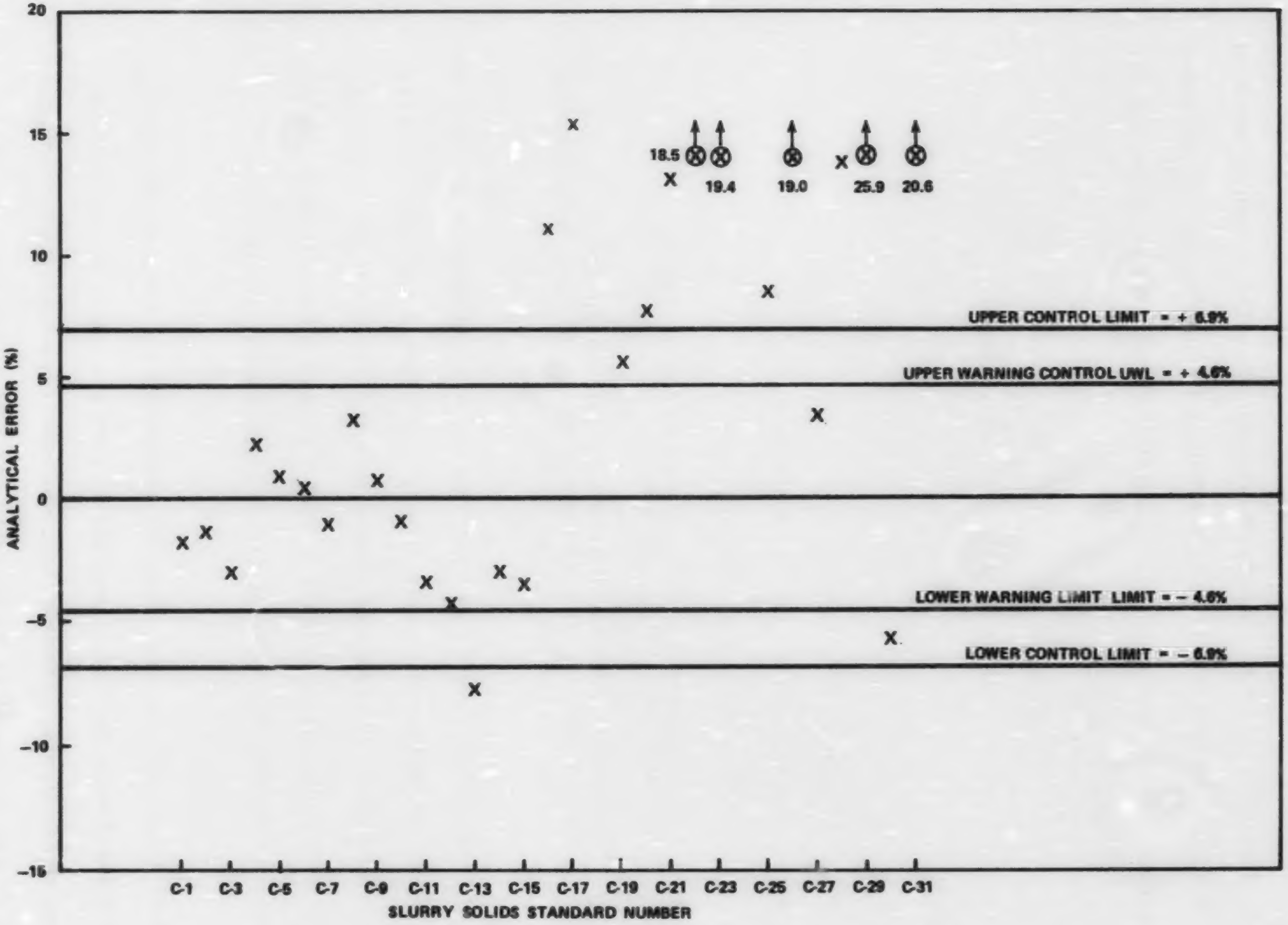

Figure 15-1. Accuracy Control Chart - Calcium by X-Ray Fluorescence (without lithium carbonate dilution)

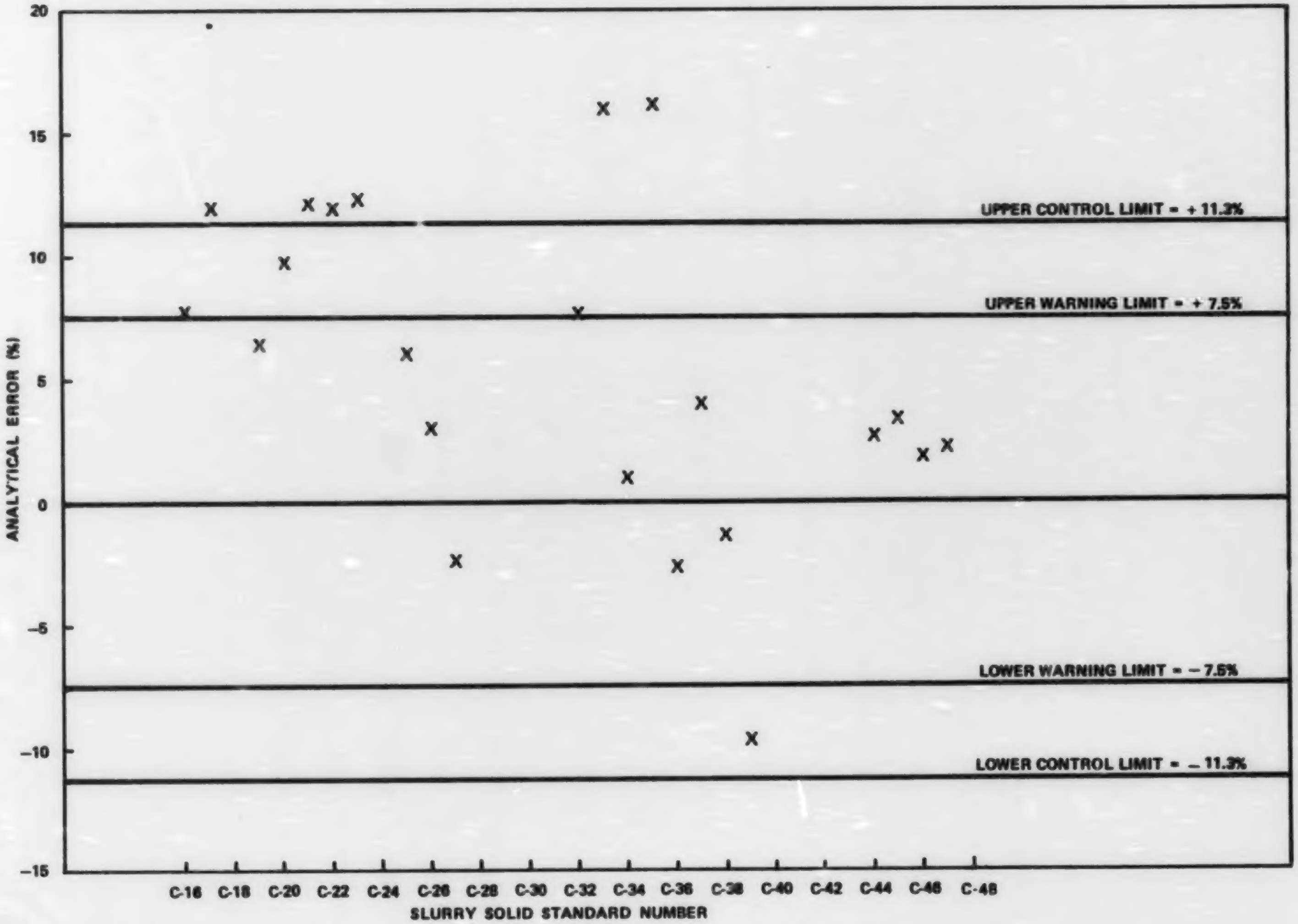

Figure 15-2. Accuracy Control Chart - Calcium by X-Ray Fluorescence (with lithium carbonate dilution)

of a measured amount of the dried solids sample with a measured amount of lithium carbonate (Li_2CO_3) before formation of the pellet.

The two X-ray fluorescence methods -- one with Li_2CO_3 and one without Li_2CO_3 -- were compared by analyzing a series of slurry solids standards. The accuracy control chart* for calcium analyses without Li_2CO_3 dilution, presented in Figure 15-1, shows that for the first 15 standards analytical errors tended to be relatively small ($<$4 percent) and to be both positive and negative, but that starting with standard C-16, errors tended to be much larger and positive. This change could be due to a change in analytical technique, a problem with the X-ray fluorescence instrument, or some other factor.

The use of the Li_2CO_3 dilution technique was started after standard C-15 in an attempt to lessen the effects of matrix interference and particle size. In the analyses of standards with Li_2CO_3 dilution, calcium errors averaged closer to zero than the errors in the analyses of the same standards without Li_2CO_3 dilution, (Figure 15-2 versus Figure 15-1) and total sulfur errors remained about the same.

After standard C-15, the average calcium error without Li_2CO_3 dilution was + 13.9 percent while the average calcium error with

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* See Reference 3, Appendix K, for procedures used in developing these accuracy control charts.

Li_2CO_3 dilution was + 5.5 percent . Since the Li_2CO_3 dilution is a technique for reducing matrix and particle size effects on X-ray fluorescence analyses, it was assumed that a large part of the problem with the original method of calcium analysis was due to these effects.

Although at first Li_2CO_3 dilution also appeared to improve the accuracy of the X-ray fluorescence analyses of total sulfur in solids, a recent reevaluation based on new analyses of the unspiked solids standard shows that Li_2CO_3 dilution slightly increased the error of the total sulfur analysis. The average total sulfur error of all standards analyzed by X-ray fluorescence without Li_2CO_3 was + 2.4 percent; with Li_2CO_3 dilution the average error was + 3.9 percent, an insignificant increase relative to the improvement achieved in the calcium analysis.

Li_2CO_3 dilution reduces the precision of both calcium and total sulfur analyses. This is indicated by the greater scatter of points on the accuracy control charts and by the larger control and warning limits, which are calculated from the average range of results of replicate sample analyses. The decrease of precision is probably caused by the increased number of steps in the analysis and by incomplete mixing of the sample with Li_2CO_3 in the mill currently used for this purpose. The use of a more efficient mixer to improve precision is being evaluated.

In June 1976, during a fly-ash-free testing period, the one part sample plus nine parts Li_2CO_3 (1:10) dilution was found to be inadequate to compensate for the matrix change when fly ash was not present. At that time, the dilution was changed from 1:10 to 1:100, and this is the dilution currently being used. Analyses of the last set of four standards (which are not fly ash free) on 11/01/76 using the 1:100 dilution had an average calcium analytical error* of +2.6 percent and an average total sulfur error of 0.4 percent. These standards were analyzed in duplicate and the average precision** was 1.9 percent for the calcium analyses and 3.1 percent for the total sulfur analyses. These encouraging results from the first four standards will be verified by more analyses of standards containing fly ash.

A fly-ash-free X-ray standard is now used for calibration on the X-ray fluorescence spectrometer for analysis of fly-ash-free samples. Preliminary results from the use of this standard have been favorable.

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* Analytical Error (X) = $\frac{Vf - Va}{Va} \times 100\%$

where Vf is the concentration value found in a standard and Va is the actual standard concentration.

** Precision (R) = $\frac{/V1 - V2/}{(V1 + V1)/2} \times 100\%$

where V1 and V2 are the concentration values obtained from analyses of a pair of samples.

15.3.3 Sulfite Analysis in Solids and Liquors

A new sulfite analysis procedure using a Wallace and Tiernan Amperometric Titrator (Method 8, Reference 7) has replaced the amperometric dead-stop procedure (Method 7, Reference 7).

The new procedure (Method 8) is used as the primary method of sulfite analysis in both solids and liquor samples. The average precision of the solids sulfite analysis was not greatly changed when Method 8 replaced Method 7, but the average precision of the liquor sulfite analysis improved from 27.2 percent to 4.8 percent.

A solid sulfite standard was analyzed in duplicate using Method 8 by each of six analysts in the Shawnee laboratory. The average analytical error was +0.4 percent. The maximum error was 0.8 percent.

15.3.4 Total Sulfur Analysis in Solids and Liquors

A new procedure has been investigated for replacing the present "wet" procedure (Method 9, Reference 7) for the analysis of total sulfur. The present procedure (a $Ba(ClO_4)_2$ titration), is used as the primary method for total sulfur in liquors and as a backup procedure for total sulfur in solids. In the new procedure, sulfites are first oxidized to sulfates with hydrogen peroxide and the total sulfate is determined turbidimetrically.

To compare the methods, two slurry liquor standards were analyzed in duplicate by each laboratory analyst. The standard analyzed by the $Ba(ClO_4)_2$ titration method (Method 9) had a large average error of +35 percent. The analyses using the turbidimetric method had an average error of -2 percent; they also had a precision that was much better than that of Method 9, indicating the presence of fewer random errors.

The titrimetric method is still being used while further comparisions of the two methods are being carried out on routine samples where interferences are likely.

Evaluation of the titrimetric analysis indicated that the precision of the method is poor when the liquor magnesium concentration exceeds 3000 ppm (see Method 9, Reference 7).

15.3.5 Carbonate Analysis in Solids

A volumetric CO_2 evolution procedure has been used as the primary method of carbonate analysis in solids (Method 5, Reference 7). The average precision of 60 pairs of analyses of carbonate in solids by

CO_2 evolution run in October 1975 was 7.3 percent. This average precision gives a precision upper control limit (UCL) of 24 percent, which is excessively large.

A new method using the laboratory's Oceanography International carbon analyzer to measure CO_2 by infrared absorption has been devised (Method 6, Reference 7). The results of analyses of carbonate standards with CO_2 concentrations at low levels were good, but technical problems were encountered at higher CO_2 concentration levels. As a result, the method is still being checked.

15.3.6 Calcium and Magnesium Analysis in Liquors

Atomic absorption spectrometry is currently the primary method used for analysis of calcium and magnesium in liquor and the backup method for analysis of calcium in solids (Method 13, Reference 7).

Although the basic method is usually quite precise and accurate, precision is reduced when large dilutions must be made. Analysis of magnesium in scrubbing liquor during magnesium factorial runs can require dilutions as great as 1:10,000.

To bypass the requirement for such dilutions, an alternative method, titration with EDTA (ethylenediamine-tetraacetic acid or its salts), is being examined for use when high concentrations are analyzed.

Section 16

SLUDGE CHARACTERIZATION

This section (1) discusses the usefulness of the settling and dewatering tests performed at Shawnee to monitor the dewatering equipment and (2) analyzes the test results with respect to operating variable levels.

16.1 TEST DESCRIPTION

Two types of tests have been used at Shawnee: the cylinder settling test and the funnel test. The settling test (see Method 20, Reference 7) measures the initial settling rate and ultimate settled solids concentration; the funnel test (see Reference 23) measures the weight percent solids of a filter cake and a specific cake resistance.

Slurry for both tests are obtained and allowed to stand overnight. The tests are then performed within 2 weeks. Comparison tests have shown that settling/dewatering results have not been appreciably affected by the differences in temperature and time between immediate (55 °C, minimum time) and delayed (21°C, 1 day to 2 weeks later) testing of the sample.

In the settling test, the slurry is mixed well in a 1000-ml graduated cylinder and allowed to settle. A slow speed rake is inserted at the bottom of the graduated cylinder to more closely model clarifier thickening. Solids interface position is recorded as a function of time until no further settling occurs. These data are plotted and the initial settling rate graphically measured. The ultimate settled solids concentration is calculated from the final solids interface level, assuming a specific gravity for the solids of 2.5. Results from this method have compared well with measurements taken by decanting the clear liquor and physically measuring the solids concentration.

The funnel test is performed by vacuum filtration of a known amount of slurry through a Buchner funnel. A piece of filter paper (of negligible resistance relative to the cake resistance) is placed in the funnel prior to filtration to help the initial cake formation. Filtration resistance is provided essentially only by the cake resistance. Filtrate volume is measured as a function of time, and cake resistance is obtained by use of the following formulas:

$$\frac{\theta}{V} = \frac{\mu r C}{2PA^2 g} V + \frac{\mu R_m}{PAg} \qquad (16\text{-}1)$$

where θ = cycle time, sec
V = filtrate volume, cm^3
μ = filtrate viscosity, g/(sec.cm), poise
r = specific cake resistance, cm/g

P = vacuum, g/cm^2
A = filter area, cm^2
g = gravity acceleration, 981 cm/sec^2
R_m = cloth resistance, cm^{-1}
C = wt. of solids/unit vol. of filtrate, g/cm^3

$$= \frac{\rho_{H_2O}}{[ci/(100 - ci)] - [cf/(100 - cf)]}$$

where ci = initial slurry percent moisture
cf = cake percent moisture
ρ_{H_2O} = filtrate density, gm/cm^3

The slope, b, estimated from a θ/V versus V plot is used in the following equation to calculate resistance:

$$r = \frac{2bPA^2g}{\mu C} \qquad (16\text{-}2)$$

16.2 TEST RESULTS

16.2.1 Operational Evaluation

Tables 16-1 through 16-4 present the results of settling and funnel tests performed on the feed stream to the dewatering equipment at the Shawnee Test Facility. Tables 16-1 and 16-2 show the results of the venturi/spray tower settling and funnel tests, respectively; Tables 16-3 and 16-4 show the results of the TCA settling and funnel tests, respectively.

Table 16-1

VENTURI/SPRAY TOWER SETTLING TEST RESULTS

Run No.	Date	Initial Settling Rate, cm/min.	Final Settled Solids, wt.%	Initial Solids, wt.%	Alkali	Fly Ash	Effective Mg^{++} Conc., ppm	Gas Rate acfm @ 330°F	L/G, gal/Mcf		EHT Res. Time, min.	Inlet pH, avg.
									V	ST		
628-1A	8/18/75	0.09	41.4	11.6	L	Yes	--	17,000 - 35,000	25 - 59	50 - 117	12	7
628-1A	9/ 2/75	0.61	46.1	8.7	L	Yes	--	17,000 - 35,000	25 - 59	50 - 117	12	7
628-1A	9/16/75	0.73	41.1	7.7	L	Yes	--	17,000 - 35,000	25 - 59	50 - 117	12	7
628-1B	9/30/75	0.30	42.7	8.7	L	Yes	--	19,000 - 35,000	29 - 53	57 - 105	12	7
702-1A	10/15/75	0.07	50.1	15.4	LS	Yes	--	35,000	21	50	20	5.8
704-1A	11/ 4/75	0.20	59.3	15.5	LS	Yes	--	35,000	21	50	20	5.8
706-1A	11/13/75	0.14	52.6	14.7	LS	Yes	--	35,000	21	50	12	5.3
706-1A	11/19/75	0.19	53.8	14.9	LS	Yes	--	35,000	21	50	12	5.3
709-1A	12/ 8/75	0.09	50.1	15.3	LS	Yes	--	35,000	21	50	12	5.8
710-1A	12/17/75	0.07	44.7	16.1	LS	Yes	--	35,000	21	50	12	6.0
711-1A	12/30/75	0.08	43.1	14.5	LS	Yes	--	35,000	21	50	6	5.7
716-1A	1/28/76	0.28	62.8	16.4	LS	Yes	3650	35,000	21	0	20	4.8
717-1A	2/ 3/76	0.04	45.7	14.9	LS	Yes	3500	35,000	21	50	6	5.5
718-1A	7/ 7/76	0.06	31.1	8.0	LS	No	--	35,000	21	50	12	5.9
718-1A	7/13/76	0.08	34.2	8.0	LS	No	--	35,000	21	50	12	5.9
718-1A	7/14/76	0.07	32.3	8.0	LS	No	--	35,000	21	50	12	5.9
718-1A	7/15/76	0.07	30.3	7.1	LS	No	--	35,000	21	50	12	5.9
718-1A	7/15/76	0.12	28.0	5.7	LS	No	--	35,000	21	50	12	5.9
718-1A	7/15/76	9.17 (floc)	27.4	5.7	LS	No	--	35,000	21	50	12	5.9
630-1A	5/13/76	0.22	38.1	8.0	L	Yes	2000	35,000	21	50	3	7.0
630-1A	5/17/76	0.41	39.9	8.0	L	Yes	2000	35,000	21	50	3	7.0
633-1A	6/ 7/76	0.56	41.5	9.0	L	Yes	2000	25,000	7	70	3	8.0
634-1A	6/21/76	2.82	46.8	4.0	L	No	--	35,000	21	50	12	8.0
634-1A	6/30/76	1.83	33.4	4.0	L	No	--	35,000	21	50	12	8.0
635-1A	7/17/76	0.13	31.1	8.0	L	No	--	35,000	21	50	12	8.0
635-1A	7/20/76	0.09	30.9	8.1	L	No	--	35,000	21	50	12	8.0
635-1A	7/25/76	0.29	39.6	8.2	L	No	--	35,000	21	50	12	8.0
636-1A	7/30/76	0.80	58.0	8.1	L	No	--	25,000	30	70	12	8.0
636-1A	8/ 3/76	0.26	50.7	8.3	L	No	--	25,000	30	70	12	8.0
637-1A	8/ 7/76	0.87	55.3	8.3	L	No	--	35,000	21	50	3	8.0
638-1A	8/17/76	1.83	44.8	3.9	L	No	--	35,000	21	50	3	8.0
638-1A	8/21/76	1.83	38.5	4.2	L	No	--	35,000	21	50	3	8.0
639-1A	9/ 1/76	1.08	36.1	4.1	L	No	--	35,000	21	50	3	8.0
640-1A	9/ 3/76	0.61	52.3	8.7	L	No	2000	35,000	21	50	3	7.0
641-1A	9/14/76	0.76	38.9	8.1	L	No	2000	35,000	21	50	3	7.0
642-1A	9/21/76	0.37	44.3	8.1	L	No	2000	35,000	5	50	3	7.0
642-1A	9/23/76	0.76	45.0	7.6	L	No	2000	35,000	5	37	3	7.0
642-1A	9/26/76	0.50	45.5	8.4	L	No	2000	35,000	5	37	3	7.0
643-1A	10/ 5/76	0.14	37.2	8.4	L	No	2000	35,000	5	37	3	7.0
VFG-1A	10/11/76	1.08	49.3	5.6	L	Yes	2000	35,000	21	50	3	7.0
VFG-1A	10/17/76	0.71	43.6	8.3	L	Yes	2000	35,000	21	50	3	7.0
VFG-1B	10/26/76	0.68	40.4	8.5	L	No	--	35,000	21	50	12	8.0
VFG-1C	11/ 1/76	1.02	52.9	8.5	L	Yes	--	35,000	21	50	12	8.0
VFG-1F	11/17/76	1.08	56.5	7.9	L	Yes	--	35,000	21	0	12	8.0
VFG-1G	11/21/76	0.87	53.2	8.9	L	Yes	--	35,000	21	50	12	8.0
VFG-1I	11/27/76	0.73	86.0	14.6	L	Yes	--	35,000	21	50	12	8.0
VFG-1P	12/ 4/76	1.67	64.3	8.0	L	Yes	--	35,000	5	50	12	8.0

Table 16-2

VENTURI/SPRAY TOWER FUNNEL TEST RESULTS

Run No.	Date	Cake Resistance, cm/g x 10^{-9}	Cake Solids, wt. %	Rotary Filter ck. sol., wt. %	Initial Solids, wt. %	Alkali	Fly Ash	Effective Mg^{++} Conc., ppm	Gas Rate acfm @ 300°F	L/G, gal/Mcf		EHT Res. Time, min.	Inlet pH, avg.
										V	ST		
635-1A	7/21/76	11.8	48	42	8.1	L	No	--	35,000	21	50	12	8.0
635-1A	7/23/76	6.8	43	43	8.2	L	No	--	35,000	21	50	12	8.0
635-1A	7/23/76(1)	4.4	42	43	8.2	L	No	--	35,000	21	50	12	8.0
636-1A	7/30/76	12.7	43	44	8.1	L	No	--	25,000	30	70	12	8.0
636-1A	8/ 3/76	11.0	40	42	8.3	L	No.	--	25,000	30	70	12	8.0
637-1A	8/ 7/76	7.5	46	46	8.3	L	No	--	35,000	21	50	3	8.0
638-1A	8/17/76	9.4	49	48	3.9	L	No	--	35,000	21	50	3	8.0
638-1A	8/21/76	6.8	54	58	4.2	L	No	--	35,000	21	50	3	8.0
639-1A	8/[illegible]/76	5.3	45	46	4.1	L	No	2000	35,000	21	50	3	7.0
639-1A	8/2[illegible]/76	5.8	48	46	4.1	L	No	2000	35,000	21	50	3	7.0
639-1A	8/27/76	5.7	46	46	4.1	L	No	2000	35,000	21	50	3	7.0
639-1A	8/27/76	5.6	47	46	4.1	L	No	2000	35,000	21	50	3	7.0
639-1A	9/ 1/76	8.8	47	51	4.1	L	No	2000	35,000	21	50	3	7.0
640-1A	9/ 3/76	4.6	47	47	8.7	L	No	2000	35,000	21	50	3	7.0
641-1A	9/14/76	4.7	43	45	8.1	L	No	2000	35,000	5	50	3	7.0
641-1A	9/14/76	4.5	43	45	8.1	L	No	2000	35,000	5	50	3	7.0
642-1A	9/21/76	5.8	48	47	8.1	L	No	2000	35,000	5	37	3	7.0
642-1A	9/23/76	5.2	47	48	7.6	L	No	2000	35,000	5	37	3	7.0
642-1A	9/26/76	4.0	48	50	8.4	L	No	2000	35,000	5	37	3	7.0
643-1A	10/ 5/76	5.9	42	41	8.4	L	No	2000	35,000	21	50	3	7.0
VFG-1A	10/11/76	3.7	55	52	8.6	L	Yes	2000	35,000	21	50	3	7.0
VFG-1A	10/17/76	3.9	53	54	8.3	L	Yes	2000	35,000	21	50	3	7.0
VFG-1B	10/26/76	5.7	42	44	8.5	L	No	--	35,000	21	50	12	8.0
VFG-1C	11/ 1/76	3.8	51	57	8.5	L	Yes	--	35,000	21	50	12	8.0
VFG-1F	11/17/76	3.2	60	60	7.9	L	Yes	--	35,000	21	0	12	8.0
VFG-1G	11/21/76	4.3	52	53	8.9	L	Yes	--	35,000	21	50	12	8.0
VFG-1I	11/27/76	4.8	53	54	14.6	L	Yes	--	35,000	21	50	12	8.0
VFG-1P	12/ 4/76	5.2	57	--	8.0	L	Yes	--	35,000	5	50	12	8.0

Note:

(1) Taken at AP-1818, all others AP-1816.

Table 16-3

TCA SETTLING TEST RESULTS

Run No.	Date	Initial Settling Rate, cm/min	Final Settled Solids, wt. %	Initial Solids, wt. %	Alkali	Fly Ash	Effective Mg^{++} Conc., ppm	Gas Rate, acfm @ 330°F	L/G, gal/Mcf	EHT Res. Time, min	Inlet pH, avg.
558-2A	8/26/75	0.09	42.8	14.3	LS	Yes	--	30,000	50	15	5.8
559-2A	9/ 8/75	0.09	49.8	15.8	LS	Yes	--	30,000	50	15	5.9
560-2A	9/24/75	0.08	50.4	16.4	LS	Yes	--	30,000	50	15	5.8
562-2A	10/ 8/75	0.12	47.5	14.3	LS	Yes	--	30,000	50	12	5.9
562-2A	10/21/75	0.08	45.3	15.5	LS	Yes	--	30,000	50	12	5.9
562-2A	10/29/75	0.13	53.4	16.0	LS	Yes	--	30,000	50	12	5.9
566-2A	11/26/75	0.16	51.9	13.8	LS	Yes	--	30,000	50	12 (3 tanks)	5.9
567-2A	12/ 3/75	0.12	48.8	15.6	LS	Yes	--	30,000	50	12 (3 tanks)	6.0
572-2A	1/ 7/76	0.11	50.1	14.4	LS	Yes	--	30,000	50	9 (3 tanks)	5.2
576-2A	1/19/76	0.09	45.5	14.6	LS	Yes	--	30,000	50	12 (3 tanks)	5.7
583-2B	4/27/76	0.05	39.9	15.2	LS	Yes	5000	30,000	50	3	5.3
584-2A	5/10/76	0.04	35.9	15.0	LS	Yes	9000	30,000	50	4.1	5.4
584-2A	5/12/76	0.04	47.0	18.0	LS	Yes	9000	30,000	50	4.1	5.4
584-2A	5/13/76	0.06	41.1	14.0	LS	Yes	9000	30,000	50	4.1	5.4
586-2A	5/24/76	0.08	44.7	15.0	LS	Yes	9000	30,000	50	4.1	5.3
587-2A	6/ 2/76	0.06	39.8	11.0	LS	Yes	9000	30,000	50	4.1	5.3
602-2A	7/14/76	0.19	47.9	15.0	L	Yes	2000	30,000	50	4.1	7.0
602-2A	7/15/76	0.23	50.1	15.0	L	Yes	2000	30,000	50	4.1	7.0
602-2A	7/18/76	0.24	49.6	14.5	L	Yes	2000	30,000	50	4.1	7.0
603-2A	7/20/76	0.83	43.3	7.7	L	Yes	2000	30,000	50	4.1	7.0
603-2A	7/26/76	0.63	40.2	7.6	L	Yes	2000	30,000	50	4.1	7.0
604-2A	7/29/76	0.63	42.2	8.1	L	Yes	2000	30,000	37	4.1	7.0
604-2A	8/ 3/76	1.08	67.9	7.5	L	Yes	2000	30,000	37	4.1	7.0
605-2A	8/11/76	0.41	42.4	8.1	L	Yes	2000	20,500	73	4.1	7.0
606-2A	8/17/76	1.08	40.2	7.5	L	Yes	2000	30,000	37	4.1	8.0
606-2A	8/18/76	0.87	41.6	7.7	L	Yes	2000	30,000	37	4.1	8.0
607-2A	8/24/76	1.05	59.9	7.6	L	Yes	4000	30,000	37	4.1	8.0
607-2A	9/ 1/76	0.61	49.1	8.6	L	Yes	4000	30,000	37	4.1	8.0
607-2A	9/ 2/76	0.63	47.0	8.2	L	Yes	4000	30,000	37	4.1	8.0
608-2A	9/ 4/76	0.49	65.6	15.8	L	Yes	4000	30,000	37	4.1	8.0
608-2B	9/13/76	0.20	50.4	15.1	L	Yes	4000	30,000	37	5.4	8.0
609-2A	9/16/76	0.63	51.2	8.1	L	Yes	2000	30,000	37	5.4	7.0
609-2A	9/23/76	0.63	43.1	8.8	L	Yes	2000	30,000	37	5.4	7.0
610-2A	10/ 3/76	1.31	43.7	7.6	L	Yes	2000	30,000	37	5.4	8.0
610-2A	10/ 7/76	1.31	51.6	8.7	L	Yes	2000	30,000	37	5.4	8.0
611-2A	10/11/76	1.31	46.2	7.9	L	Yes	2000	30,000	37	4.1	8.0
612-2A	10/18/76	0.92	49.4	8.0	L	Yes	2000	30,000	37	3.0	8.0
613-2A	10/21/76	0.71	54.7	8.4	L	Yes	2000	30,000	50	3.0	7.0
614-2A	10/27/76	0.68	44.0	8.4	L	Yes	2000	30,000	37	16	8.0
615-2A	11/ 3/76	0.61	51.6	8.7	L	Yes	2000	30,000	50	12	7.0
617-2A	11/21/76	0.23	53.2	14.8	L	Yes	--	30,000	50	12	8.0

Table 16-4

TCA FUNNEL TEST RESULTS

Run No.	Date	Cake Resistance, cm/g x 10^{-9}	Cake Solids, wt. %	Rotary Filter ck. sol., wt. %	Initial Solids, wt. %	Alkali	Fly Ash	Effective Mg^{++} Conc., ppm	Gas Rate, acfm @ 330°F	L/G, gal/Mcf	EHT Res Time, min.	Inlet pH, Avg.
603-2A	7/23/76	4.6	62	--	7.6	L	Yes	2000	30,000	50	4.1	7.0
604-2A	8/ 3/76	4.1	52	--	7.5	L	Yes	2000	30,000	37	4.1	7.0
605-2A	8/11/76	4.4	54	53	8.1	L	Yes	2000	20,500	73	4.1	7.0
606-2A	8/17/76	3.9	52	--	7.5	L	Yes	2000	30,000	37	4.1	8.0
606-2A	8/18/76	2.9	56	--	7.7	L	Yes	2000	30,000	37	4.1	8.0
607-2A	8/24/76	3.7	50	52	7.6	L	Yes	4000	30,000	37	4.1	8.0
607-2A	9/ 1/76	4.4	55	--	8.6	L	Yes	4000	30,000	37	4.1	8.0
607-2A	9/ 2/76	3.8	50	--	8.2	L	Yes	4000	30,000	37	4.1	8.0
608-2A	9/ 4/76	1.7	53	--	15.8	L	Yes	4000	30,000	37	4.1	8.0
608-2B	9/13/76	1.4	52	--	15.1	L	Yes	4000	30,000	37	5.4	8.0
609-2A	9/16/76	3.7	49	--	8.1	L	Yes	2000	30,000	37	5.4	7.0
609-2A	9/23/76	5.2	55	--	8.8	L	Yes	2000	30,000	37	5.4	7.0
610-2A	10/ 3/76	3.9	59	--	7.6	L	Yes	2000	30,000	37	5.4	8.0
610-2A	10/ 7/76	4.4	53	--	8.7	L	Yes	2000	30,000	37	5.4	8.0
611-2A	10/11/76	3.7	54	--	7.9	L	Yes	2000	30,000	37	4.1	8.0
612-2A	10/18/76	2.9	54	--	8.0	L	Yes	2000	30,000	37	3.0	8.0
613-2A	10/21/76	3.4	55	--	8.4	L	Yes	2000	30,000	50	3.0	7.0
614-2A	10/27/76	3.2	52	--	8.4	L	Yes	2000	30,000	37	16.0	8.0
615-2A	11/ 3/76	2.4	54	--	8.7	L	Yes	2000	30,000	50	12	7.0
617-2A	11/21/76	3.4	53	--	14.8	L	Yes	2000	30,000	50	12	8.0

As a rule, settling and dewatering tests have been successfully used to monitor the clarifier and filter operation to determine if upset conditions are being caused by changes in the settling or dewatering characteristics of the discharge slurry. For example, settling test results indicated that solids in the clarifier overflow during Run 718-1A resulted from the unusually low solids settling rate of the discharge slurry. A flocculation agent was required to continue operation, and the settling test was employed to determine addition requirements. The settling test can also be used to find out if the clarifier area is adequate. The few checks that have been run have indicated adequate clarifier area. Not enough clarifier upsets have occurred, however, to ascertain the accuracy of this method in determining impending clarifier upset.

The funnel test provides a good check of filter operation since the cake solids concentration measured by the funnel test agrees well with the cake solids obtained by the filter as shown in Figure 16-1. Cake resistance, on the other hand, shows only a very weak correlation with cake solids concentration, shown in Figure 16-2.

16.2.2 Correlation with Operating Variables

Settling Tests. Analysis of the settling test results has revealed little clear-cut relationship between settling characteristics and operating

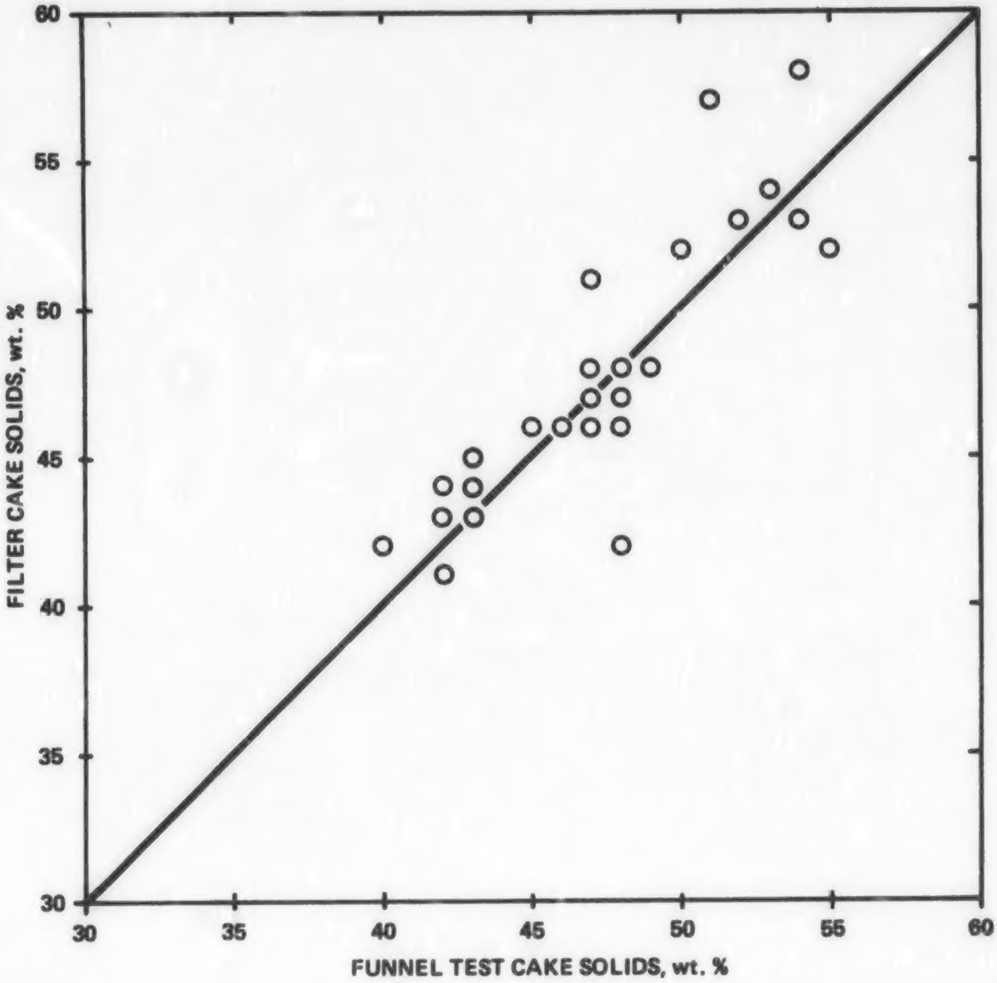

Figure 16-1. Filter Cake Percent Solids Versus Funnel Cake Percent Solids for All Runs Using the Filter

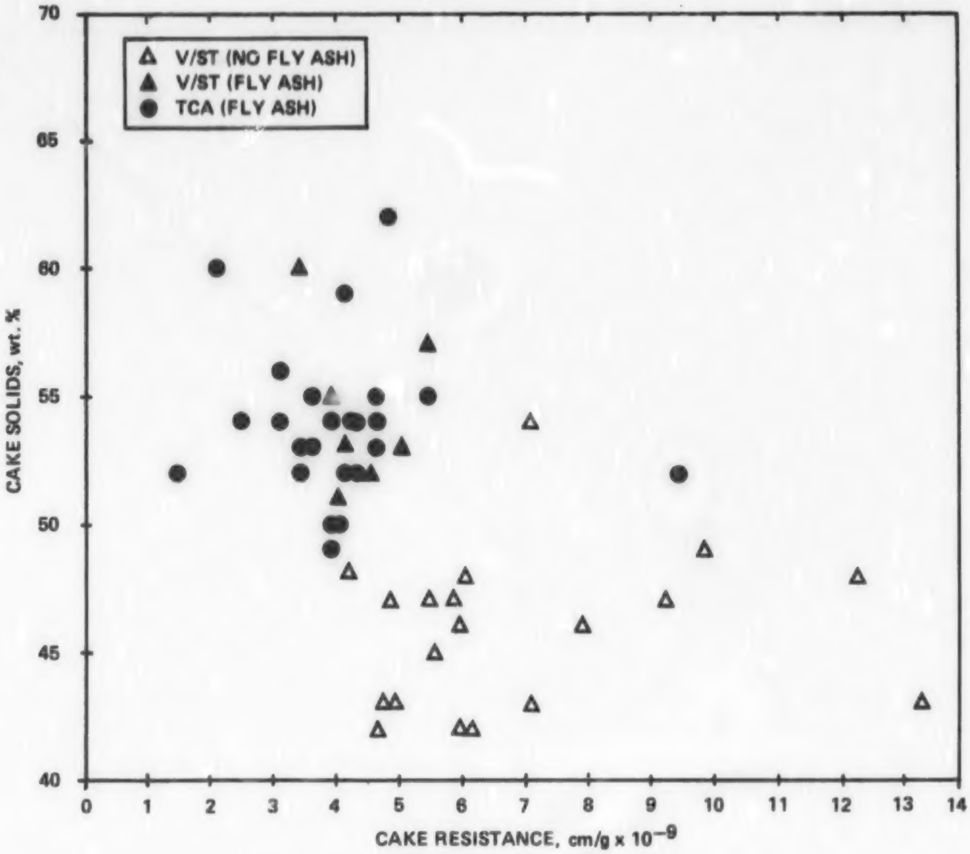

Figure 16-2. Funnel Test Cake Percent Solids Versus Cake Resistance

variables. Plots of initial settling rate versus final amount of settled solids for different initial percent solids (Figure 16-3 for the venturi/spray tower system runs and Figure 16-4 for the TCA system runs) indicate initial settling is faster at lower initial solids concentration over the conditions investigated.

Figures 16-5 and 16-6 are plots of the within-run replications for runs where more than one settling test was performed. The variation in ultimate settled solids within a run ranges from 1 weight percent to as much as 26 weight percent, while initial settling rate varies from zero to eight times. With such a large variation in replicate values, very little can be concluded from comparison plots of these runs since the between-run differences are the same magnitude as the replicate value ranges. To obtain valid comparisons, it will be necessary to generate better averages by obtaining a larger number of data points at each set of operating conditions.

Another question to be resolved is whether the large within-run variation in test results is real and caused by small changes in operating conditions or false and due to poor technique either in sampling or test performance. It is most likely that the variation is real since very little can go wrong with a settling test either in sampling or performance. More data at a given set of test conditions should resolve this question. A broad spread of the data would support real variations while a narrow grouping with a few "flyers" would support a conclu-

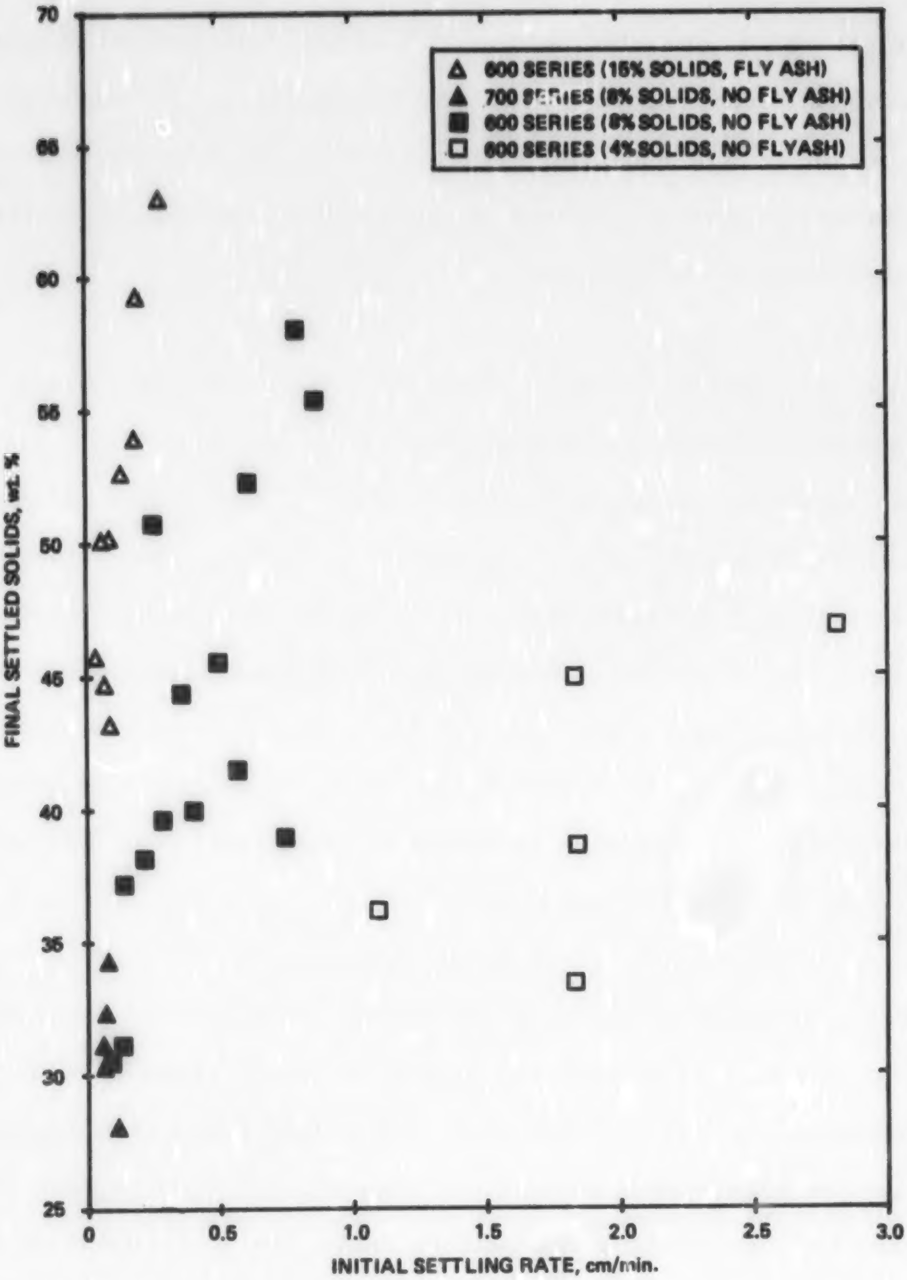

Figure 16-3. Final Settled Solids Versus Initial Settling Rate as a Function of Weight Percent Solids Recirculated for the Venturi/Spray Tower System

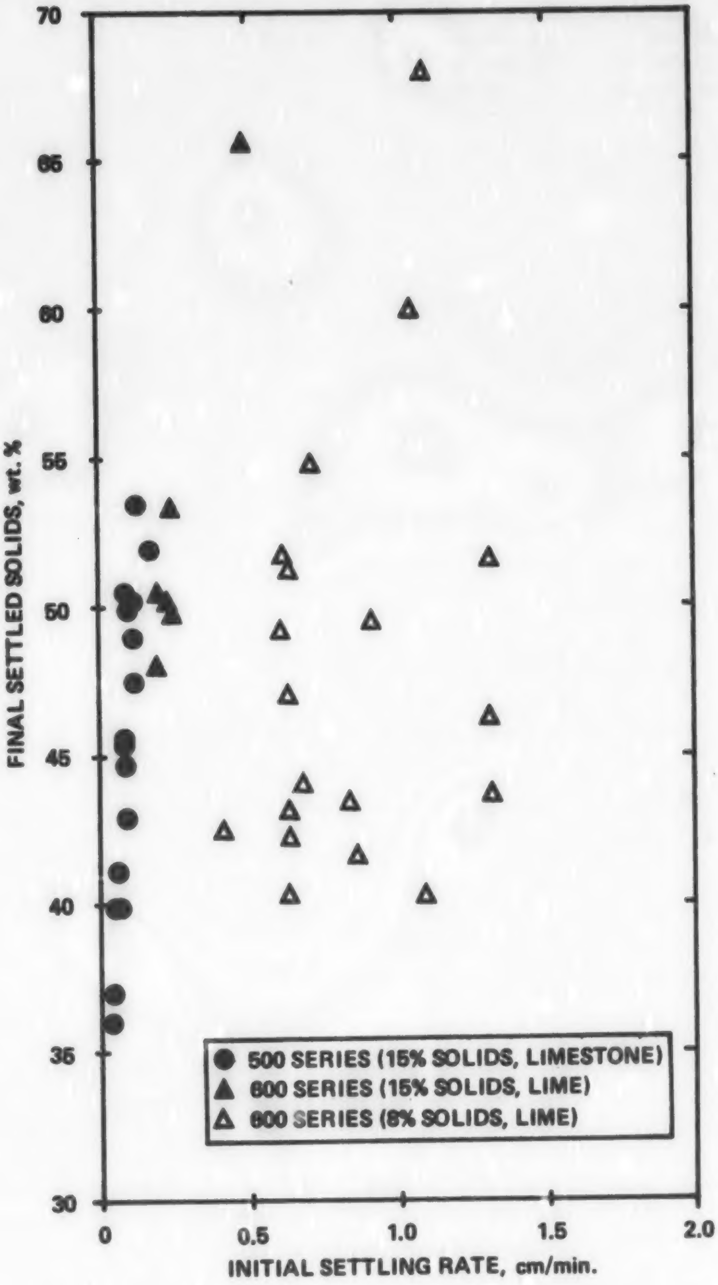

Figure 16-4. Final Settled Solids Versus Initial Settling Rate as a Function of Weight Percent Solids Recirculated for the TCA System

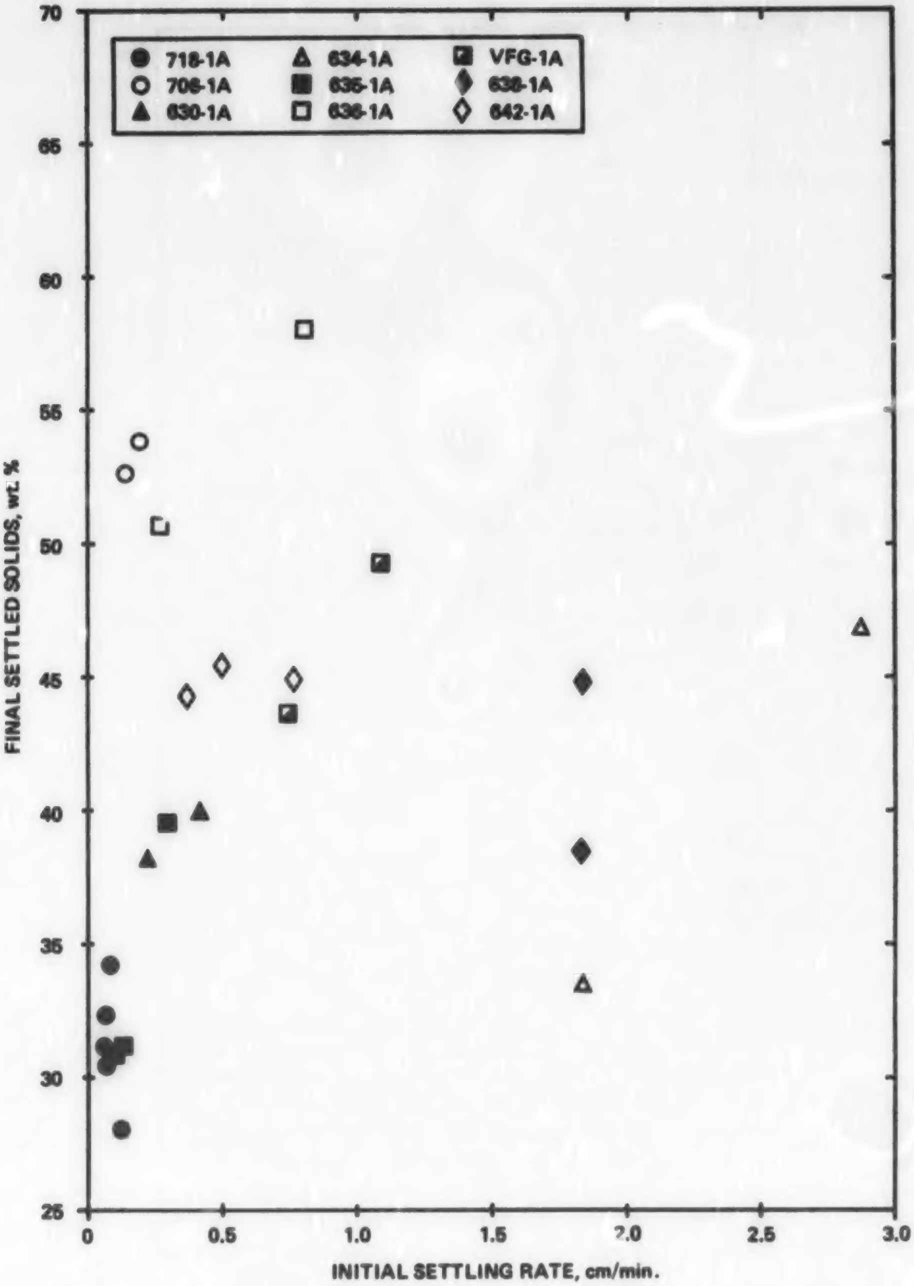

Figure 16-5. Final Settled Solids Versus Initial Settling Rate for the Venturi/Spray Tower System

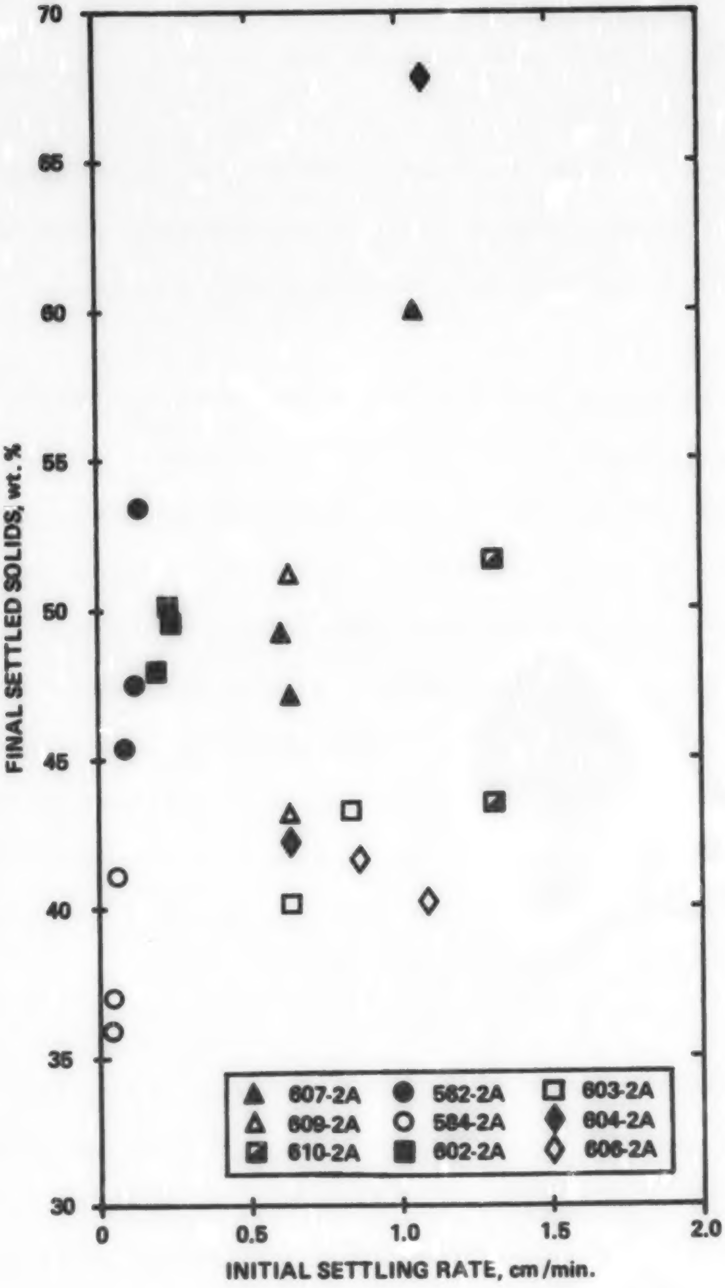

Figure 16-6. Final Settled Solids Versus Initial Settling Rate for the TCA System

sion that the "flyers" were not valid test results.

Funnel tests. Cake resistance shows little correlation with cake percent solids (see Figure 16-2), and comparison plots of resistance as a function of operating variable were not constructed.

Filtered cake solids, however, correlates strongly with fly ash content (see Table 16-2 and 16-4). On the TCA system, all the runs where funnel tests were performed were lime addition tests with fly ash in the flue gas (the 600 series tests). On the venturi/spray tower system, the 600 series tests were with lime addition without fly ash, and the VFG series were with lime addition with fly ash, except for VFG-1B, which was fly ash free. On all tests where fly ash was present, cake solids ranged from 49 to 56 percent, while all tests without fly ash had cake solids in the 42 to 48 percent range. This is strong evidence that the presence of fly ash aids in the filtration of the discharged slurry.

Most run variables seemed to have little effect on the cake solids concentration, except in Run 638-1A where, with no fly ash at low percent solids recirculated (4 percent), the filtered cake averaged 51.5 percent solids. (This was the only fly-ash-free run with a cake solids above 50 percent.) When MgO was added at these conditions (Run 639-1A), the average cake solids fell to a more typical 46 percent. This is the only run where MgO addition resulted in a significant change in filter cake percent solids.

16.3 FUTURE PLANS

Data collection will continue, and an attempt will be made to perform a larger number of tests for some runs. Analysis of the settling data with a view to specifying clarifier size for the TVA economic study program will be attempted.

As part of an ongoing analysis of filter performance, filter leaf tests will be performed on a large range of cloths to determine if the optimum cloth type is being used at Shawnee.

16.4 CONCLUSIONS

The following conclusions can be made:

- Settling test results, consisting of initial settling rate and final settled solids concentration data, are useful aids in monitoring clarifier performance
- Cake resistance measurements show little correlation with cake solids concentration. However, the cake solids concentration, through its good agreement with filter cake solids concentration, provides a good check of the filter performance
- Initial settling rate increases with decreasing initial percent solids over all of the run conditions investigated
- Owing to the large variation in replicate values, no significant correlation between operating variables and initial settling

rate or ultimate settled solids was found. It remains to be proved or disproved whether the large variations between replicates are real process variations or the result of poor technique, either in sampling or test performance

- Funnel test results indicate that cake solids concentration is higher for lime tests with fly ash than without fly ash. Values ranged from 49 to 56 percent for tests with fly ash to 42 to 48 percent for tests without fly ash

Section 17

OPERATING EXPERIENCE DURING LIME/LIMESTONE TESTING

This section summarizes the operating experience during lime/limestone testing, with and without fly ash in the flue gas and with and without magnesium addition, at the Shawnee Test Facility from mid-February 1976 through November 1976. Summaries of prior operating experience are presented in References 1, 2 and 3.

17.1 SCRUBBER INTERNALS

17.1.1 Mist Eliminators

Throughout this testing period, three-pass, open-vane, stainless-steel chevron-type mist eliminators were used in both the venturi/spray tower and the TCA systems. Monitoring of mist eliminator performance during this period further confirmed the relationship between mist eliminator reliability and alkali utilization. During the 3930-hour (1449 with limestone and 2481 with lime) magnesium addition test block, the restriction of the mist eliminator remained under 5 percent except for three lime tests - Runs 604-2A, 606-2A and

613-2A - during which abnormally high solids oxidation was experienced due to air leakage through the downcomer. Details of mist eliminator performance during utilization testing at Shawnee are reported in Reference 3.

17.1.2 TCA Grid Supports

The 3/8-inch diameter, 316 stainless steel bar-grids, installed on 1-1/4 centers on October 1973, have been in slurry service for approximately 22,000 hours with no evidence of significant erosion.

17.1.3 TCA Spheres

During this test period, all three TCA beds were stocked with new 6.3-gram solid nitrile foam spheres obtained from Universal Oil Products' Air Correction Division. The foam spheres have been in continuous service for almost 1/2 year (3888 hours) without significant failure. With the previously tested hollow thermoplastic rubber (TPR) spheres, over 11 percent of the spheres had failed at this service life (Reference 3, Figure 10-1).

In the first 1773 hours of operation with the foam spheres, the losses in diameter and weight were 12 percent and 4 percent, respectively. Continued exposure of the spheres for an additional 2115 hours resulted in a 23 percent diameter loss and 21 percent weight loss. Figure 17-1 illustrates the spheres diameter loss during the monitoring program. Comparison of the performance of these 6.3-gram nitrile foam spheres with 6.5-gram nitrile foam spheres tested during the earlier reporting period indicate a significant improvement in quality. The latter spheres had suffered a 9 percent diameter loss and a 1 percent weight loss in merely 240 hours of operation. Visual examination of the present foam spheres before and after exposure yielded the same results as noted in Reference 3.

17.1.4 Spray Tower Nozzles

Two types of nozzles have been tested in the venturi/spray tower, Bete No. TF48FCN 316 stainless steel nozzles and Bete No. ST48FCN 316 stainless steel nozzles with stellite diffusers. The TF nozzles were made out of one piece of 316 stainless steel whereas the ST nozzles consisted of three pieces - base and collar nut made of 316 stainless steel and diffuser made of stellite.

Eight Bete stainless steel nozzles (No. TF48FCN) were tested for 1565 hours on lime/fly ash-free slurry. During the testing period, the average flow rate per nozzle was 50 gpm at a 10 psi pressure drop. Most of the operation, approximately 1200 hours, was with 8 percent solids slurry. The remainder was with 4 percent solids

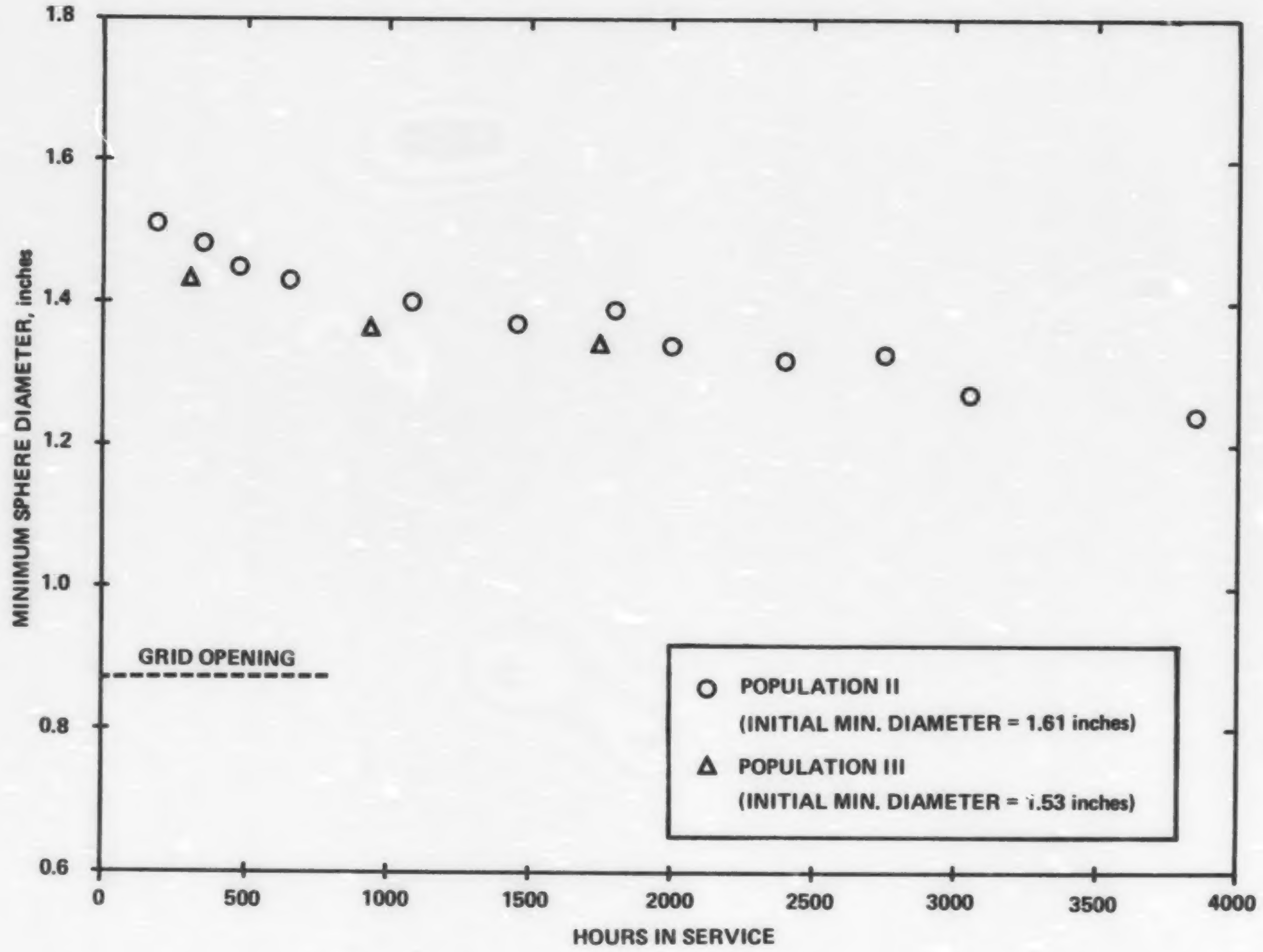

Figure 17-1. Erosion/Shrinkage Rate of Nitrile Foam Spheres

slurry. During the testing, individual nozzles lost from 0.93 to 2.43 percent of their initial weight because of erosion.

Earlier testing of these nozzles before the Advanced Test Program with lime and limestone slurries containing fly ash had resulted in an average weight loss of approximately 28 percent in 4320 hours, a considerably higher erosion rate than observed in operation with fly-ash-free slurry. During this earlier testing period, conditions for the stainless steel nozzles were as follows:

- 923 hours with 15 percent solids, limestone/fly ash slurry, 43 gpm per nozzle at 10 psi, only two of the four slurry spray headers in service
- 1135 hours with 8 to 10 percent solids, limestone/fly ash slurry, 43 gpm per nozzle at 10 psi, all four spray headers in service
- 2262 hours with 7 to 9 percent solids, lime/fly ash slurry, 43 gpm per nozzle at 10 psi, all four spray headers in service

Most nozzle testing in the venturi/spray tower system during the Advanced Test Program has been with Bete No. ST48FCN nozzles with stellite diffusers. These nozzles were installed in March 1974. They provided almost uninterrupted service till their removal on December 6, 1976. During the 17,500-hour test period, 27 nozzles were used. Only two nozzles had to be replaced during the test period.

During the final removal of the stellite diffusers, the impact of the pipe wrench on the collar nut connecting the stellite diffuser to the base fractured ten of the diffusers near their tips. Inspection of these nozzles revealed that the major portion of the nozzle wear was confined to the diffusers. In the 17,500-hour test period, the average thickness of the diffuser dropped to 0.193 inches from an initial value of 0.260 inches. This amounts to a reduction of 26 percent. Thickness measurements made to estimate the relative wear of the diffusers are included in Table 17-1. The maximum erosion of the base, measured by a diameter increase, was 20 percent after 10,685 hours in service.

17.1.5 TCA Nozzles

The four TCA slurry feed nozzles were installed in September 1974. These were Spraco No. 1969F full-cone, open-type nozzles, made of 316 stainless steel. Except for slight pitting of the diffuser vanes, no significant wear had been observed after 15,000 hours of operation at a 5 psi pressure drop with slurry containing 8 to 15 percent suspended solids. This lack of wear rate is probably due to the low pressure drop across the nozzles.

The three inlet gas duct cooling spray nozzles are Bete No. ST32FCN nozzles with stellite diffusers. These nozzles were installed on

Table 17-1

MEASUREMENTS OF STELLITE DIFFUSER THICKNESS, INCHES

	Stellite Diffusers Thickness, in.	
	Diffusers with Broken Tips	Diffusers without Broken Tips
	0.153	0.176
	0.189	0.243
	0.154	0.174
	0.181	0.168
	0.194	0.208
	0.191	0.211
	0.172	0.224
	0.178	0.141 (thinnest)
	0.208	0.188
	0.191	0.187
		0.221
		0.209
		0.195
		0.234
		0.245
Average	0.181	0.202

Note:

1. Average of the 25 readings was 0.193 inches and they ranged from 0.141 to 0.245 inches. A new diffuser measures approximately 0.260in. at this point.

March 7, 1975. After 11,566 hours of operation, the diffusers of two nozzles were so eroded that only one complete turn of the spiral tip remained. The three nozzles were replaced with identical units. Their performance will be monitored closely.

17.1.6 Venturi Internals

The venturi at Shawnee is a variable-throat, 316L stainless steel type manufactured by Chemical Construction Corporation (Chemico). During the current operating period, both erosion and minor corrosion have continued. The problems encountered and their remedies are discussed below.

A small circumferential leak between the venturi top and the inlet gas duct was repaired by bending a piece of 3/8-inch stainless steel rod to fit the crevice and then seal welding along its top and bottom.

The original sliding guide vanes had badly eroded, some to the point where adjusting bolts required replacement. Rather than fabricate new guide vanes, it was decided to spot weld the present guide vanes to prevent them from falling out of position. In addition, two quarter-circle pieces were fabricated and welded over the two areas of greatest erosion at the fixed support for the guide vanes.

The flanges on the shroud at its top and bottom had eroded badly and the rubber gaskets were no longer sealing. New flanges and gaskets of the same design were fabricated on site and installed. A discussion of the materials used through April 1975 can be found in TVA's Third Interim Report on Corrosion Studies (Reference 3). Materials tested after April 1975 are reported in TVA's Fourth Interim Report on Corrosion Studies, Appendix L of this report.

Blisters were observed in the rubber lining of the 4-inch piping to the tangential nozzles and the bull nozzle. One such blister was slit for attempted repair with epoxy, but it was not successfully reglued. The rubber was cut out and the spot coated with epoxy.

17.2 REHEATERS

Flue gas from the scrubber is reheated to prevent condensation and corrosion in the exhaust system, to facilitate isokinetic and analytical sampling, to protect the induced-draft fans from solid deposits and droplet erosion, and to increase plume buoyancy.

The original in-line, fuel-oil-fired units (supplied by Hauck Mfg. Co.) were modified in March 1974 (venturi/spray tower) and May 1975 (TCA) to incorporate a fuel-oil-fired external combustion chamber (manufactured by Bloom Engineering Co.). Reasons for the changes are discussed in Reference 1. Both of the units have operated reliably since the modifications with minimum flameout and equipment problems for over 19,300 hours on the venturi/spray tower system and 8,000 hours on the TCA system.

17.3 FANS

The 316L stainless steel fans at the Shawnee Test Facility are induced-draft, centrifugal fans manufactured by Zurn Industries. Reliability has been good during the current operating period, with no system downtime due to fan problems.

Cleaning the fans, fan dampers, and ductwork between the dampers and reheaters has been greatly facilitated by the use of a portable steam generator. The steam generator has also been useful in thawing frozen lines during winter.

17.4 PUMPS

The major pump problem during the current operating period (see Reference 3 for a report on prior operation) has been pump seal failure. The seals on the rubber-lined centrifugal pumps (manufactured by Allen-Sherman-Hoff) are air-flushed packings. The frequency of repacking of the 20- to 100-gpm pumps has been halved from once every 70 to 110 hours to one every 120 to 220 hours by maintaining the clearance between the shaft and the pump casing at 10 to 15 mils.

In another attempt to solve the seal problem at Shawnee, mechanical seals have been tested on various centrifugal pumps. These tests are part of the equipment components testing program, and the results are covered in Subsection 17.8.2.

17.5 WASTE SOLIDS HANDLING

17.5.1 Filter

Because of frequent cloth failure and cake discharge difficulties, the Maxi-belt rotary-drum filter was converted from a roll-discharge type to a snap-blowback discharge type in February 1975. The cloth life was extended by this change. Further improvement in average cloth life has been experienced by reducing the adjustment range of the cake deflector blade during this reporting period. Prior to this modification, the filter cloth would occasionally get caught in the blade and tear when the blade was moved too near the cloth. Table 17-2 summarizes details of the cloths tested, their service life and their failure mode.

Table 17-2

FILTER CLOTH PERFORMANCE

Filter Cloth Type	Before Modification of Scraper Assembly		After Modification of Scraper Assembly	
	Service Life, Hours	Failure Modes	Service Life, Hours	Failure Modes
Lamports Polyester S-4048-SHS	56-203	• Deterioration of Transverse Seam • Holes in Cloth • Tearing by Scraper	Not Tested	---
Lamports Polypropylene 7512-SHS	42-560	• Holes in Cloth • Tearing by Scraper • Blinding	349-866	• Deterioration of Transverse Seam • Holes in Cloth • Blinding
Technical Fabricators Polypropylene TFI-9162	Not Tested	---	866	• Blinding
Ametek Polyolefin ST-EF9D8-HJO	165-603	• Holes in Cloth • Tearing by Scraper	Not Tested	---

17.5.2 Centrifuge

The centrifuge being used at Shawnee is a Bird 18 x 28 inch continuous Solid Bowl centrifuge fitted with two alternative gear units (80:1 and 40:1) and a 5-inch (distance between flights) single lead conveyor with a Type B tip. The bowl is a cylinder 10° configuration, and the motor is equipped with a drive sheave to produce a speed of 2100 rpm. At the rated speed of 2100 rpm, the centrifuge develops a centrifugal force of 1,050 g.

Owing to the abrasiveness of the fly ash in the feed slurry, the hard facing on the centrifuge, consisting of Stellite 1016 on the blade tips of the conveyor and Colmony #6 on the pushing faces of the conveyor, wore off the conveyor blades after 1400 hours of operation. The rotating assembly of the unit was sent to the factory where the same hard facing materials were reapplied. Following repair, the centrifuge operated reliably for another 4750 hours, at which time the centrate quality deteriorated. Inspection by the vendor revealed the following - cake plows were worn 60% in the outboard area, the bowl head plows were in excellent condition, and the solids weir on the bowl head was worn in the outboard area of the spokes. The conveyor was worn progressively worse from the effluent end to the cake discharge end, from 3/8-inch down to 5/8-inch maximum wear. The forward feed compartment discharge parts were worn on the trailing edges and needed replacing. The feed trunnion and spline trunnion journal area showed some signs of wear and grooving in seal areas.

The rotating assembly of the unit was sent to the factory, in May 1976, for rebuilding. Since this last repair, the unit has operated satisfactorily for 3350 hours.

17.5.3 Clarifiers

The 6-foot feedwell extension on the TCA clarifier (to give a total of 8 feet), installed during the May 1975 boiler outage, has successfully reduced clarifier upsets and subsequent high solids content in the clarifier overflow. The only maintenance performed on the clarifier during this reporting period was the overhaul of the TCA clarifier rake timer.

17.6 ALKALI ADDITION SYSTEMS

17.6.1 Lime

The lime addition system consists of a storage silo, a screw feeder, a lime slaker (manufactured by Portec-Cahaba), a slaked-lime holding tank, and associated feed pumps. An analysis of the lime used can be found in Appendix C. Fresh water slakes the lime to approxi-

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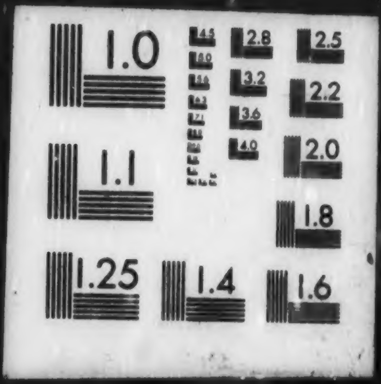

mately 20 to 25 weight percent solids. The system has given excellent reliability in over 22,500 hours of intermittent operation. Plugging of the lime addition lines by gradual buildup of grit that gets through the slaker screen has been reduced by placing a screen over the entrance to the slaked lime slurry hold tank.

17.6.2 Limestone

The limestone addition system consists of a drying-grinding system, a dry storage tank, a weigh belt feeder, a slurry tank, and an associated feed pump.

The drying-grinding system was installed during an earlier EPA-sponsored dry-limestone injection program at the Shawnee Power Station. In general, it has given satisfactory performance with low maintenance since the beginning of the alkali wet-scrubber test program more than 4 years ago.

The slurry addition system was modified to provide 60 weight percent limestone slurry in November 1972 and was further modified to incorporate clarified process liquor for slurrying the limestone in March 1974. Since March 1974, the system has continued to operate satisfactorily for an additional 17,000 hours of intermittent operation with little maintenance.

The alkali addition system pumps are positive displacement pumps manufactured by Moyno Pump Division of Robbins & Myer Co. They were installed in November 1972 when the limestone system was converted to provide a 60 weight percent limestone slurry. The pumps are oversized by a factor of 2. They are allowed to wear until the required flow can no longer be maintained. Operating life has been short, 2000 hours for a rotor and 1000 hours for a stator.

A composition and size distribution analysis of the ground limestone can be found in Appendix C.

17.7 INSTRUMENT OPERATING EXPERIENCE

17.7.1 pH Meters

The main problem associated with the Uniloc Model 321 submersible pH meters (Universal Interloc, Inc., Santa Ana, Calif.) used to measure scrubber liquor pH has been occasional scale formation on the probes. This scale causes measurement error and is removed by rinsing with hydrochloric acid whenever electrode response becomes sluggish. All probes are routinely rinsed with water and calibrated at least twice a week.

A new type of micro-junction reference was installed in the TCA submersible pH electrode. The reference cell was filled with potassium nitrate instead of potassium chloride. A 5 percent silver chloride solution was also added. No significant difference was noted between the performance of this electrode and the electrode used previously.

17.7.2 Flow Meters

In Reference 1, it was reported that the Adiprene-L liner in the 1-1/2-inch Foxboro magnetic flow meters deteriorated. Subsequently, it was noted that these lines were tapered in thickness near the meter exit while all the other meter sizes had a uniform lining thickness. As a result, the meters were relined with Adiprene-L of uniform thickness, and since that time no liner failures have been experienced.

Recently, Foxboro discontinued the 1800 series meters that are used at Shawnee. Instead the company now offers the more compact 2800 series only. The new, 1-1/2 inch or smaller, magnetic flow meters are teflon-lined rather than Adiprene-L-lined. Adeprene-L-lined meters are available in the 2- to 36-inch-size range. Satisfactory meter accuracy has been maintained by electrical purging once per shift and flow checks approximately once every 3 months.

17.7.3 Level Measurement

Three Brooks Maglink 5300 Series level indicators were installed in scrubber effluent hold tanks D-101, D-201, and D-208 for evaluation at the Shawnee Test Facility. The Brooks indicator consists of a vertically mounted standpipe or stilling chamber fastened externally or internally to the side of a tank, with a bottom liquor inlet to the chamber. Slurry level is detected by a donut-shaped float surrounding a small center pipe running the length of the stilling chamber. A magnet inside the sealed center pipe moves with the float and provides a level signal from its position.

The initial problem was solids buildup on, and eventual immobilization of, the float. A liquor flush stream was installed to eliminate the problem, but the following difficulties are occasionally encountered.

- Floating material still occasionally immobilizes the float
- The flush system liquor stream impinges on the float, causing float depression and reading error. The magnitude of the error is variable and dependent on the distance the purge stream free falls before impinging on the float
- Dislodging an immobilized float can uncouple the magnet. Reactivating the system can take several manhours
- Modifying the measurement range requires the installation of a new gear drive

However, when properly maintained and calibrated and when a constant flush of about 2 gpm of slurry or clarified liquor is used, the Brooks indicator measures the slurry level in the effluent hold tank to within 6 inches. A dipstick level measurement is taken every hour to verify the Brooks indicator reading.

17.7.4 SO_2 Meters

Operation with the Du Pont Model 400 UV SO_2 analyzers has been essentially trouble-free during the current operating period. The units are calibrated on Monday, Wednesday, and Friday of each week using a set of calibrated filters.

17.7.5 Density Meter

The performance of the Dynatrol density meter has been excellent for monitoring the density of the makeup alkali (both lime and limestone).

For monitoring the density of the scrubber system slurry streams, the performance of the Dynatrol meter has been unsatisfactory. It is believed that scaling inside the U-tube may be contributing to the meters' unreliability.

17.7.6 NO2 Meters

Following equipment changes specified by Du Pont, several unsuccessful attempts have been made to convert the idle Marble-Bed SO_2 analyzers to NO_2 measuring service. The problem has been referred to Du Pont's Applications Engineering Department.

17.8 MATERIALS AND EQUIPMENT EVALUATION PROGRAM

17.8.1 Materials

Lining or coating materials for equipment at the Shawnee Facility generally consist of neoprene rubber (pipes, pumps, scrubber internal walls, and small tanks) or Flakeline 103 (effluent hold tanks and clarifiers). Flakeline 103 is a bisphenol-A polyester resin filled 25 to 35 percent with glass flake. It is manufactured by Ceilcote Company.

Both rubber and Flakeline coatings have shown very little erosion or other deterioration. Recently testing of three test panels provided by Ceilcote Company was completed. Approximately one-third of the exposed surface of each panel was covered with one of three Ceilcote formulations: Flakeline 103, Caroline 505AR, and Flakeline 151. Only the Flakeline 103 test panel mounted inside one of the TCA beds exhibited significant wear after being exposed for 6634 hours. The panels were returned to Ceilcote Company in August 1976 for evaluation.

For operational expendiency, successful repairs have been made using Epoxylite-203 (Epoxylite Corp., Anaheim, California), an epoxy resin formulated with selected fillers, making a paste material. The resin is cured with Epoxylite's No. 301 amine hardener. A patch on the venturi/spray tower effluent hold tank agitator blade has shown little wear after more than 19,000 hours.

In a recent test, a few selected areas of neoprene lining, glass surfaces and stainless steel surfaces (mist eliminator vanes) were cleaned and McLube No. 1700 coating was applied. This material is designed for keeping ship hulls free of barnacles. Results appear negative for this first trial on these surfaces. In fact, the tops of coated mist eliminator vanes held more solids than did some noncoated vanes in the immediate vicinity. It is probable that the coating did not cure or dry exactly as desired and thus did not develop its full potential. Other applications will be made in the selected areas and greater attention will be paid to the curing requirements.

The Fourth Interim Report on Corrosion Studies at the test facility, written by TVA, is presented in Appendix L. The report covers the operating periods from July 1975 through August 1976 and discusses corrosion and erosion of the test facility equipment and the results of the materials of construction evaluation carried out simultaneously. Results of the later phases of the current operating period will be presented in the Fifth Interim Report.

17.8.2 Equipment

A program to evaluate selected mechanical components has been initiated at the Shawnee Test Facility. A York Demister, plastic pipe, Hayward line-strainers, knife gate and butterfly valves, mechanical seals, and a sonic level tank sensor are currently being evaluated. Results are summarized below.

York Demister. The York Demister was installed at a location downstream from the three-vane chevron mist eliminator. No provisions for washing the York Demister were made. The Demister was 3.5 inches thick and had two adjacent sections that overlapped because the Demister's diameter exceeded the scrubber's inside diameter. Because of rapid solids deposit on the inlet face, operation was not successful. The pressure drop across the York Demister increased by 1.00 inch of water pressure after 3 days' service. Approximately 30 percent of the inlet face was plugged, but penetration into meshes was only 5 percent.

Plastic Pipe. A section of Bondstrand Series 4000 fiberglass - reinforced plastic pipe was installed on the suction side of the TCA recirculating pump during this period and is currently being tested. Details on a high-impact polyvinyl chloride pipe tested earlier in the same spot are reported in Reference 3.

Line Strainer. Dual-basket, in-line Elliott strainers were originally installed at the discharge of pumps G-201 and G-204 to alleviate the problem of nozzle plugging with debris and other foreign material. During the 1975 boiler outage each Elliott strainer was replaced by two single-basket, in-line Hayward Strainers which were mounted in parallel at the discharge of each pump. The replacement of the Elliott strainers became necessary because of the serious erosion that developed in the outlet necks. For the Elliott strainer on G-201 discharge, erosion was also observed on edges where the slide gate sealed each basket chamber.

Results of inspections of the 6-inch single-basket Hayward strainers on G-204 discharge, after approximately 8000 hours of service was as follows:

- Erosion at several locations on the basket support ledge. At two of the locations, where severe erosion had occurred, about 80 percent of the ledge had disappeared
- Severe gouging, as much as 1/4 inch deep, of the discharge throat was observed at two locations
- Minor erosion along the inlet flange face, lower half portion of the south unit
- A triangular-shaped erosion spot 6 mm deep in the discharge throat of the south unit
- Grooves up to 13 mm deep in the north strainer outlet throat
- Two erosion areas in the basket support flange
- Baskets of both units in good condition

For the 8-inch strainers on G-201 discharge, the condition after approximately 10,600 hours of service revealed:

- A small erosion spot about 20 mm long at the bottom of the discharge throat of the south strainer
- Some erosion of the basket support ledge of both strainers. This erosion was not very extensive
- Baskets of both units in good condition

Knife Gate Valves. The knife gate valves being tested at Shawnee are type 316 stainless steel Fabri-Valves.

There are a total of eight such valves in service - four on the Hayward strainers on G-201 discharge and four on the Hayward strainers on G-204 discharge. The O-rings from each of the valves have been removed during recent outages.

Inspection during this reporting period has been confined mainly to the four 6-inch Fabri-Valves on G-204 outlet. Pertinent observations are summarized below.

All O-ring grooves were filled with solids. All four valves could be operated by the hand wheel, after application of grease on the stems and in the knife gate slots. Observations specific to each valve are:

- The valve on the downstream side of the north Hayward strainer had very slight rounding of the knife gate at the 6 o'clock position, slight erosion of the valve body on the downstream edge at the 11 o'clock position, and small amounts of scale on the downstream face of the knife gate
- The valve on the upstream side of the north Hayward strainer had no bodily erosion and only slight rounding of the knife gate at the 6 o'clock position. Thin, smooth scale was found on the suction side. This valve has a guide piece instead of a backup half-ring provided in the other valves
- The valve on the downstream side of the south Hayward strainer had no bodily erosion and only slight rounding of the sharp edge of the gate. The backup ring had a couple of weld spots that had smoothed off

The valve on the upstream side of the south Hayward strainer had no noticeable erosion. White, hard, 10 mil-thick was scale on the upstream face. This scale was not removed. The exterior bodies of all four valves appeared in good condition. Operation of these valves without O-rings has sometimes resulted in slight leakage past the gate when the basket was being emptied, but this is not a very serious problem. The actual thickness of the gate was not remeasured this time because no loss had been detected previously. The deposition of hard scale on the gate is perhaps the major factor that would make the valve hard to operate and was the major contributor to the failure of the O-rings when they were in service.

Butterfly Valves. A 6-inch Durco manual block valve (throat and disc coated with abrasion-resistant polyethylene) and a Valtek 6-inch butterfly control valve are being evaluated.

The Durco valve is located in the pump G-204 discharge line (G-204 feeds two of the spray tower headers). A total of 3700 hours of service in 8 percent slurry at approximately 9 ft/sec slurry velocity through the valve (in full-open position) resulted in a 4.5 mil loss of the disc coating thickness. This represents about 10 percent of the total coating thickness. The throat was in good condition and there was no leakage through the valve when it was leak-tested at 55 psig. A late inspection after approximately 8000 hours in slurry service showed no erosion of either the polyethylene-coated disc or the valve body liner. All wetted surfaces held a thin scale coating which was left intact. To date this valve has provided excellent service.

The Valtek valve was last inspected April 16, 1976. At that time, the body of the valve showed some small fissures in the body bore that were up to 3/4 inch long, and a great amount of erosion had taken place in the lower half of the valve body. The two deepest grooves were 0.180 and 0.162 inch. In contrast to the body failure, the stellite-coated disc showed some slight waviness of the disc edge thickness.

This valve had 1551 hours wide-open and 3302 hours throttling service at the time of the April 1976 inspection. Performance of this value for slurry service has been judged unsatisfactory.

Fisher 2-Inch Control Valve. This butterfly valve was originally installed on the discharge of pump G-204 at start of Run 640-1A. Minor pitting was seen on the leading (upstream) edge along the rear face. Pitting was found to a greater extent on the back face than on the front face where a few pits were seen. A magnifier is needed to see these shiny pits, which were estimated to be 2 to 3 mils deep and 10 mils in diameter. The rear half of the disc (trailing edge) where the fish tail is located appeared to be in good condition, as did the valve body.

Mechanical Seals. Durametallic-type "CRO" mechanical seals were installed on pumps G-105 (venturi/spray tower system bleed) and G-205 (TCA system bleed). The seal on G-105 failed after approximately 1500 hours of service; however, one of its carbon inserts was broken when it was installed. The seal on G-205 failed after 6300 hours of service. Current experience indicates that proper installation and maintenance of the mechanical seal is critical for satisfactory performance. More experience with these seals will be required to determine if proper installation and maintenance can be achieved on a routine basis.

Sonic Tank Level Sensor. An Echo-Sonic level indicator (manufactured by Endress and Hansen, Inc.) is presently being evaluated.

__Future Evaluations__. Scheduled for future testing and evaluation are a Metritape level sensor, a cone-diaphragm check valve in clarified liquor service, and both polybutylene and PVC pipe for slurry circulation.

Section 18

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APPENDIX A

CONVERTING UNITS OF MEASURE

Appendix A

CONVERTING UNITS OF MEASURE

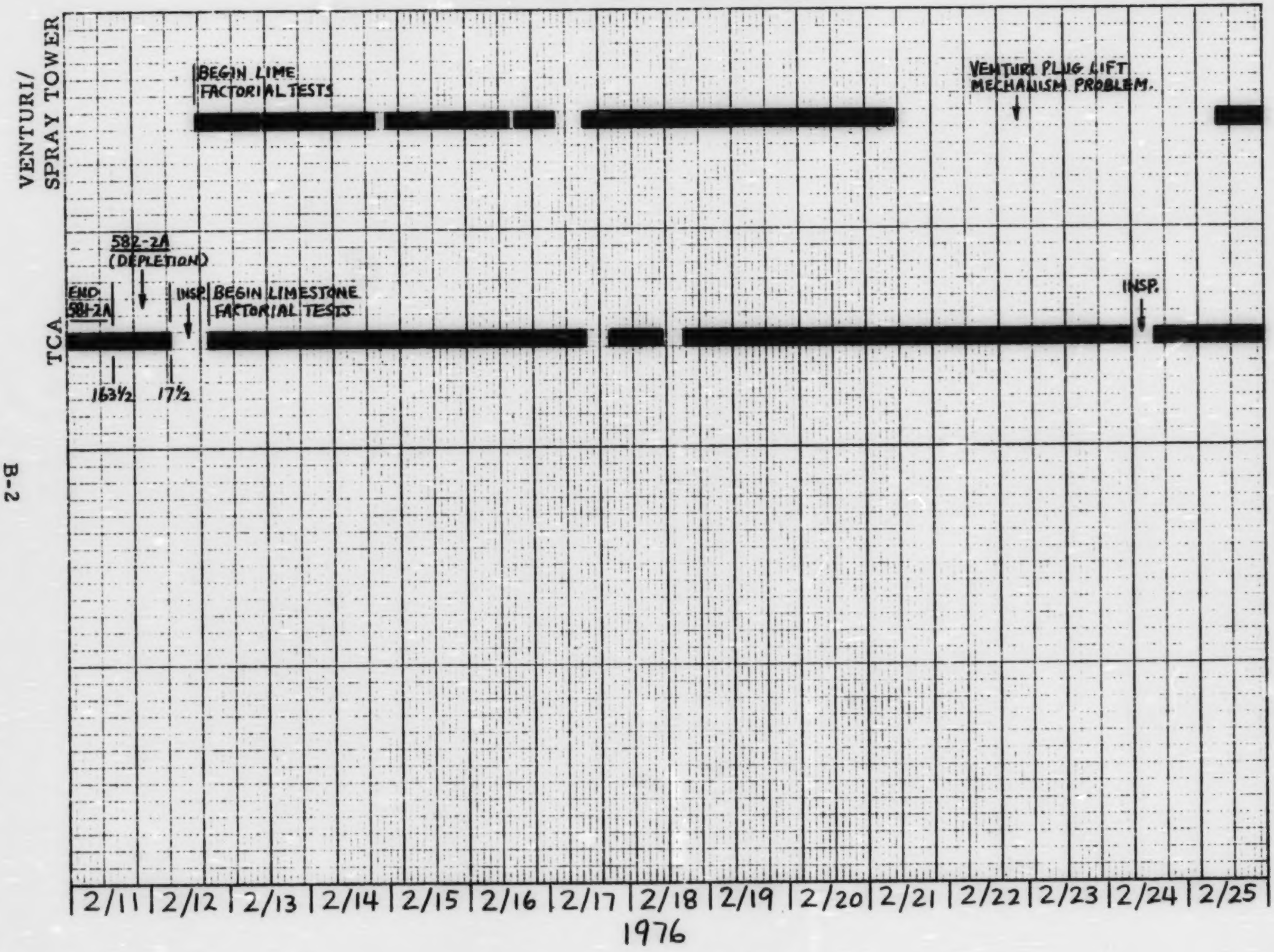
Environmental Protection Agency policy is to express all measurements in Agency documents in metric units. In this report, however, to avoid undue costs or lack of clarity, English units are used throughout. Conversion factors from English to metric units are given below.

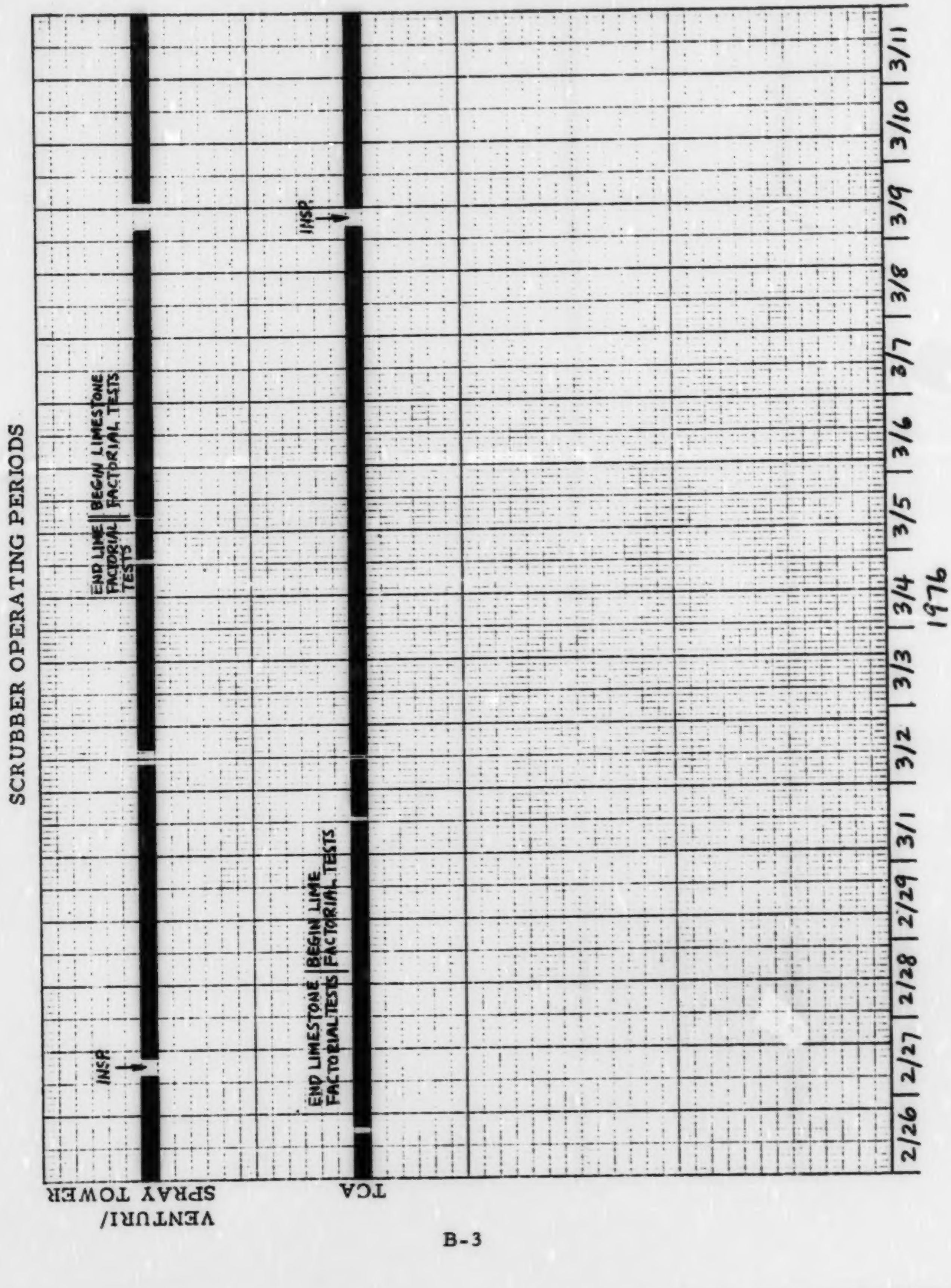
To Convert From	To	Multiply By
scfm (60° F)	nm /hr (0° C)	1.61
cfm	m /hr	1.70
°F	°C	(°F-32)/1.8
ft	m	0.305
ft/hr	m/hr	0.305
ft/sec	m/sec	0.305
ft^2	m^2	0.0929
ft^2/tons per day	m^2/metric tons per day	0.102
gal/mcf	l/m^3	0.134
gpm	l/min	3.79
gpm/ft^2	$l/min/m^2$	40.8
gr/scf	gm/m^3	2.29
in.	cm	2.54
in. H2O	mm Hg	1.87
lb	gm	454
lb-moles	gm-moles	454
lb-moles/hr	gm-moles/min	7.56
lb-moles/hr ft^2	gm-moles/min/m^2	81.4
lb-moles/min	gm-moles/sec	7.56
psia	kilopascal	6.895

APPENDIX B

SCRUBBER OPERATING PERIODS

SCRUBBER OPERATING PERIODS

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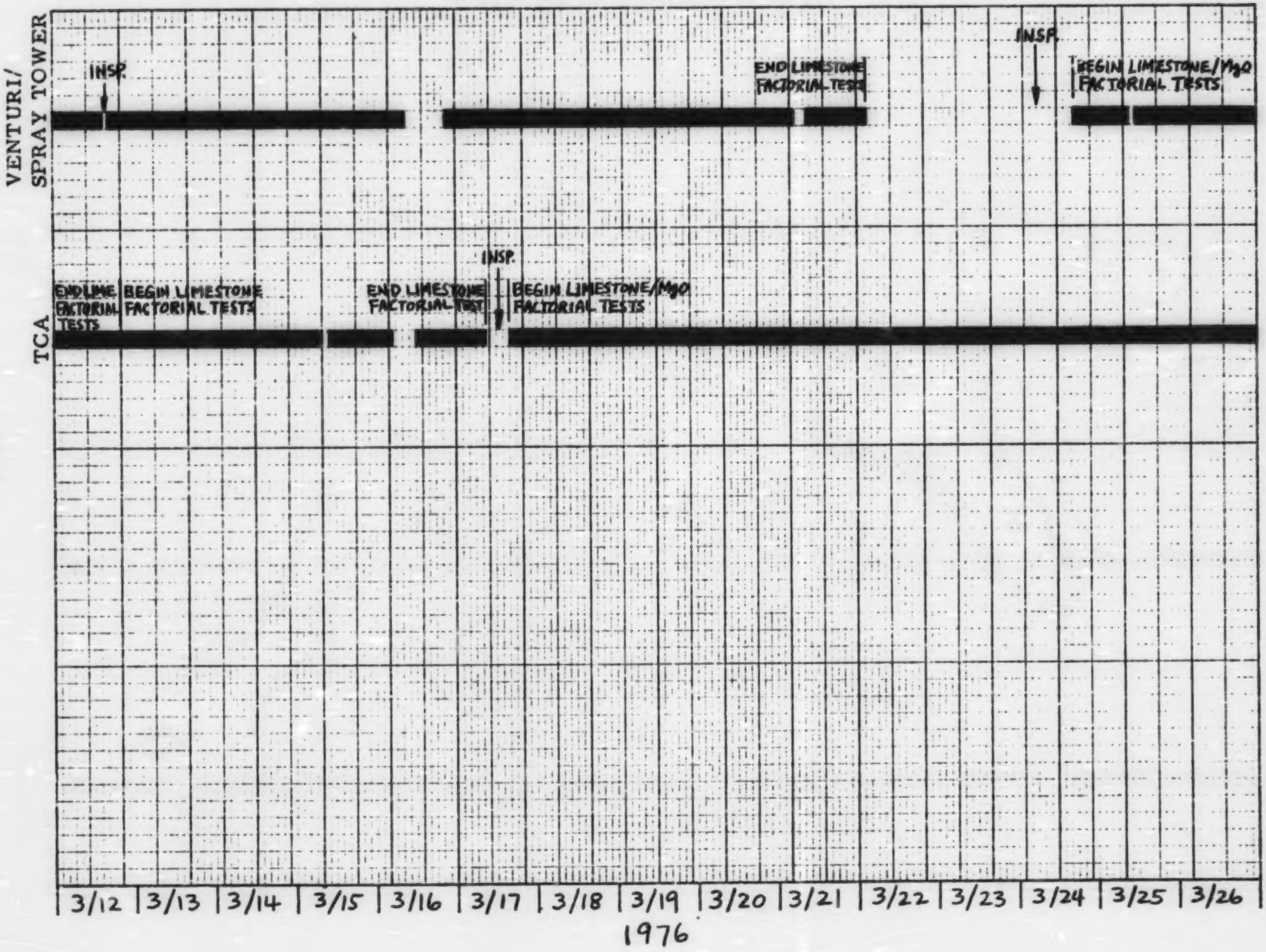

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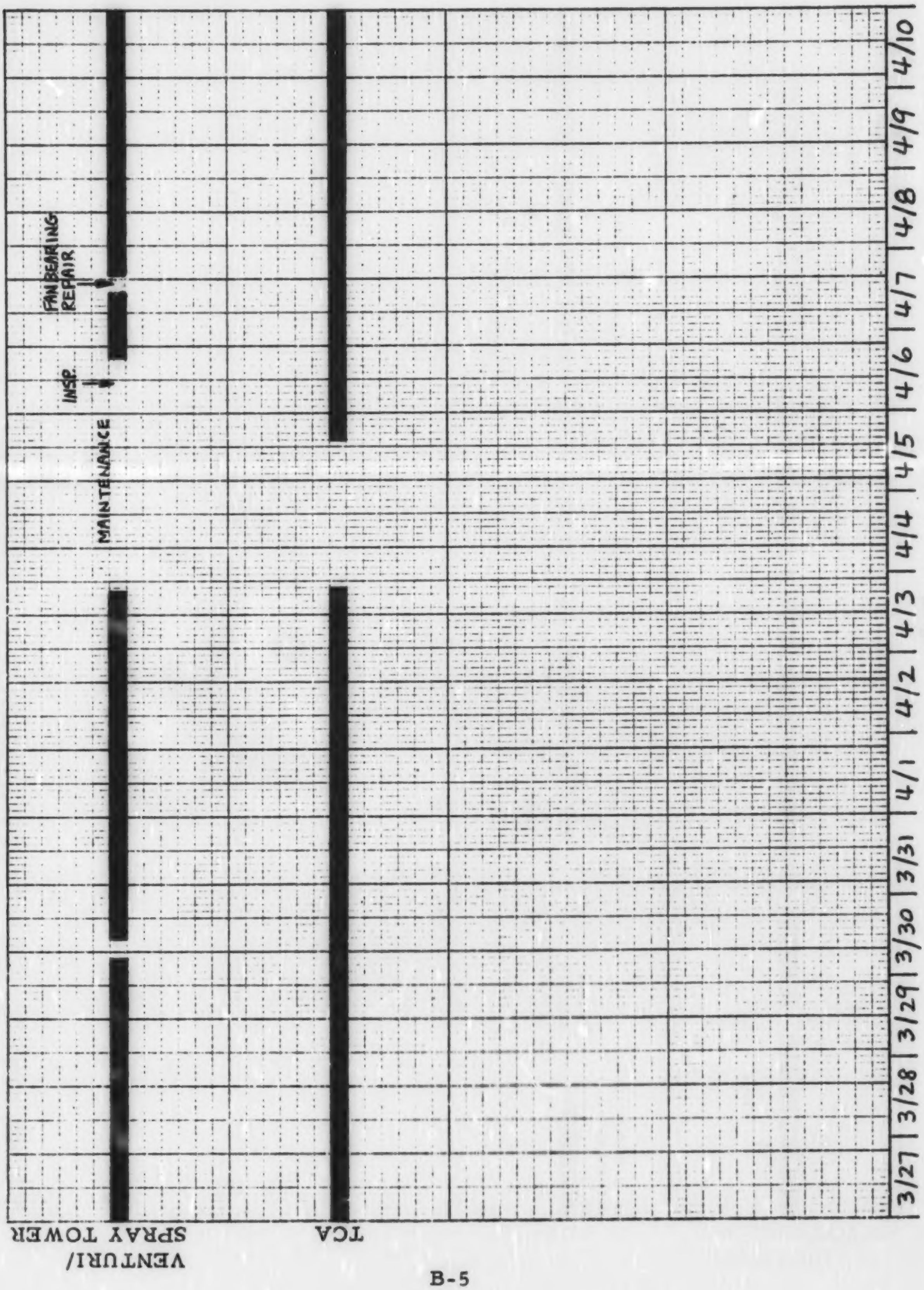

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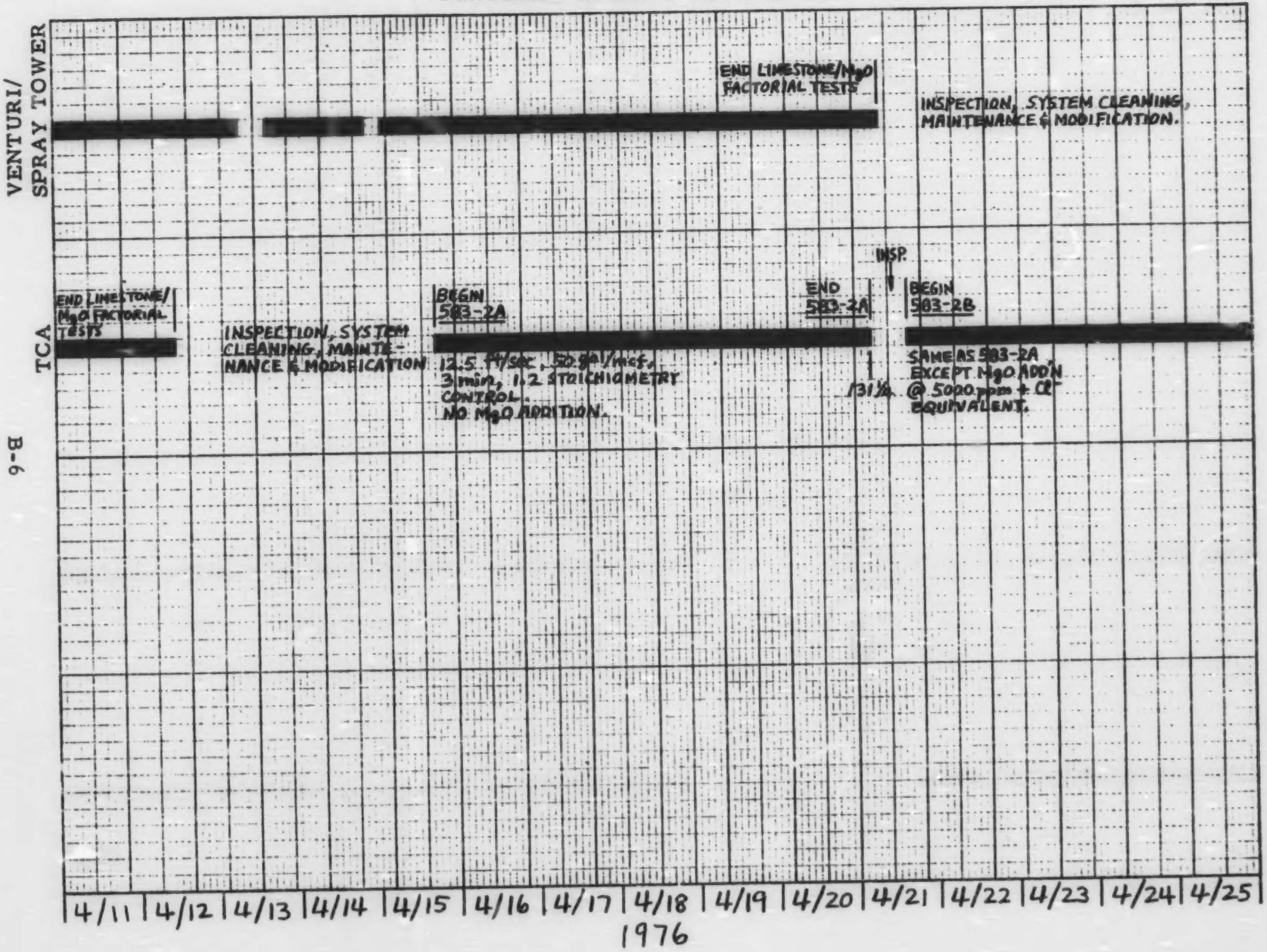

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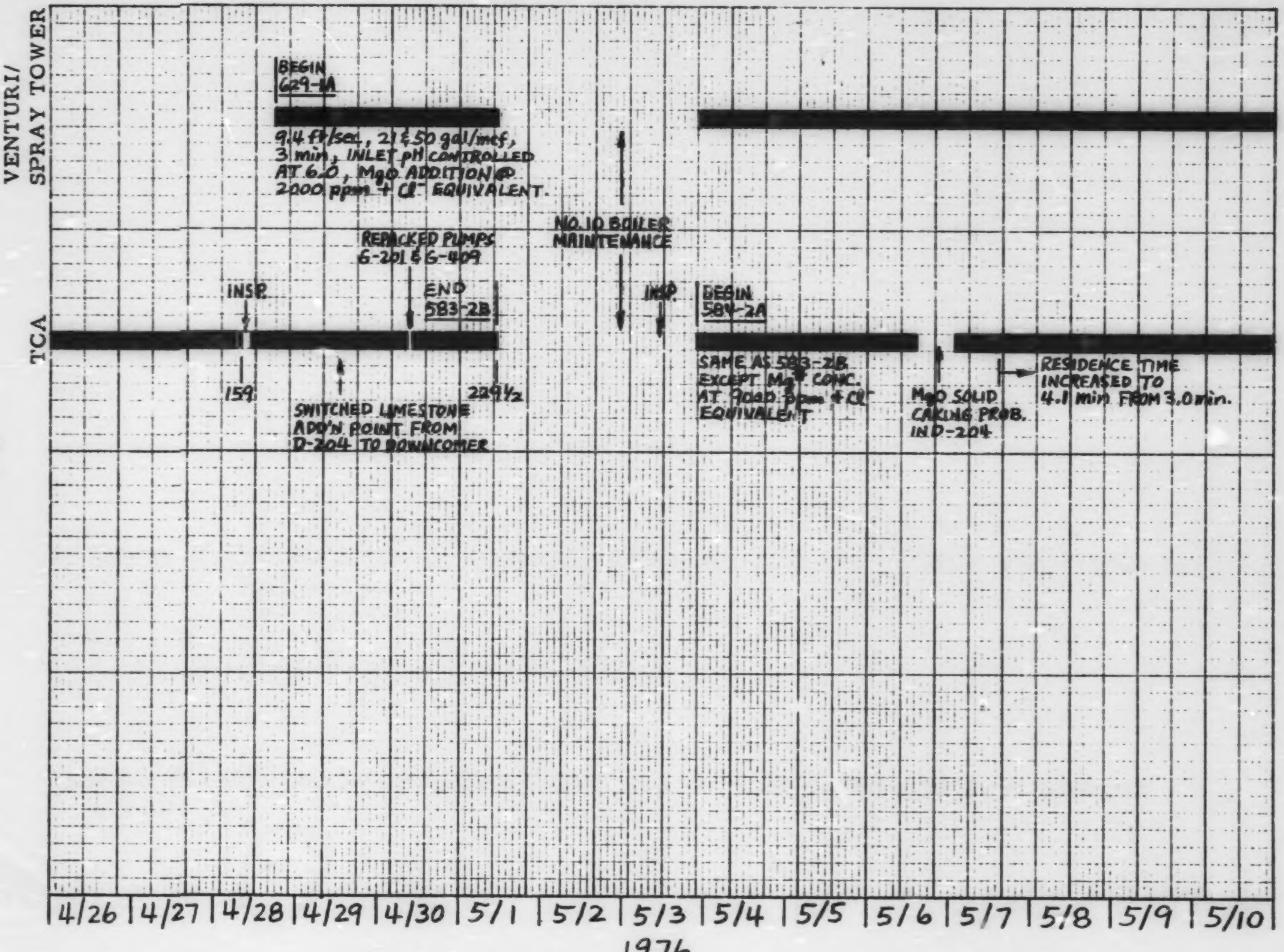

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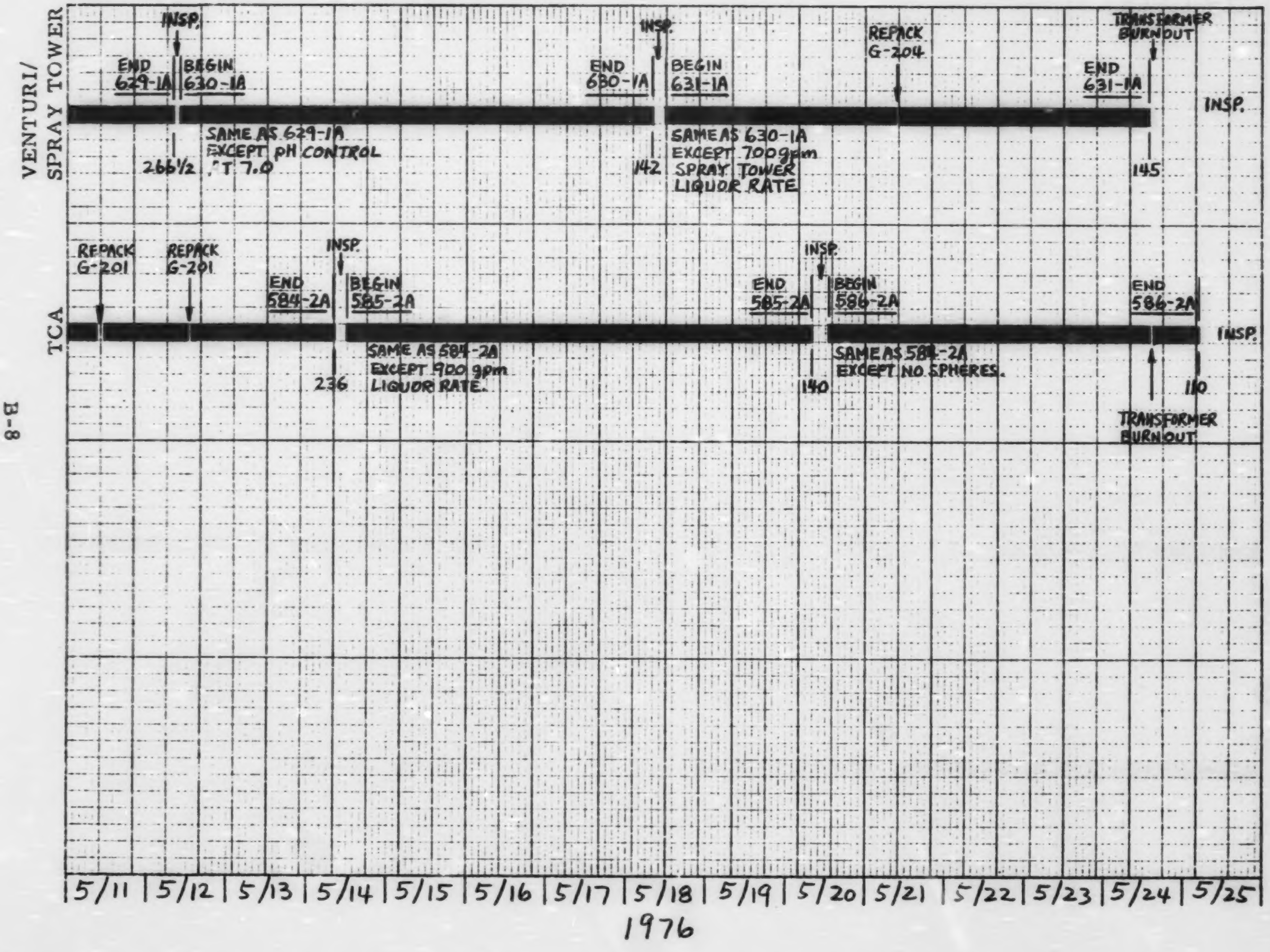

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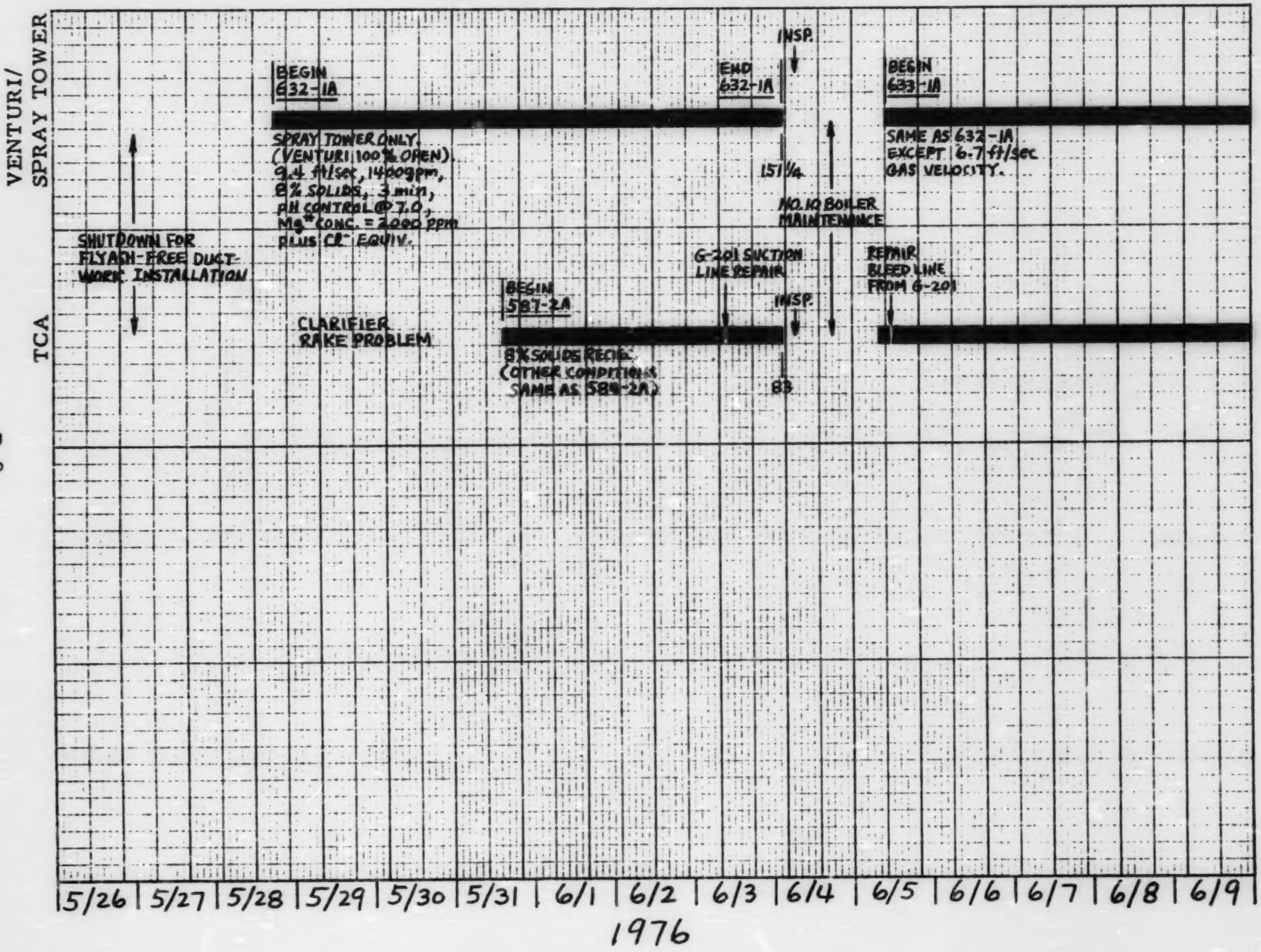

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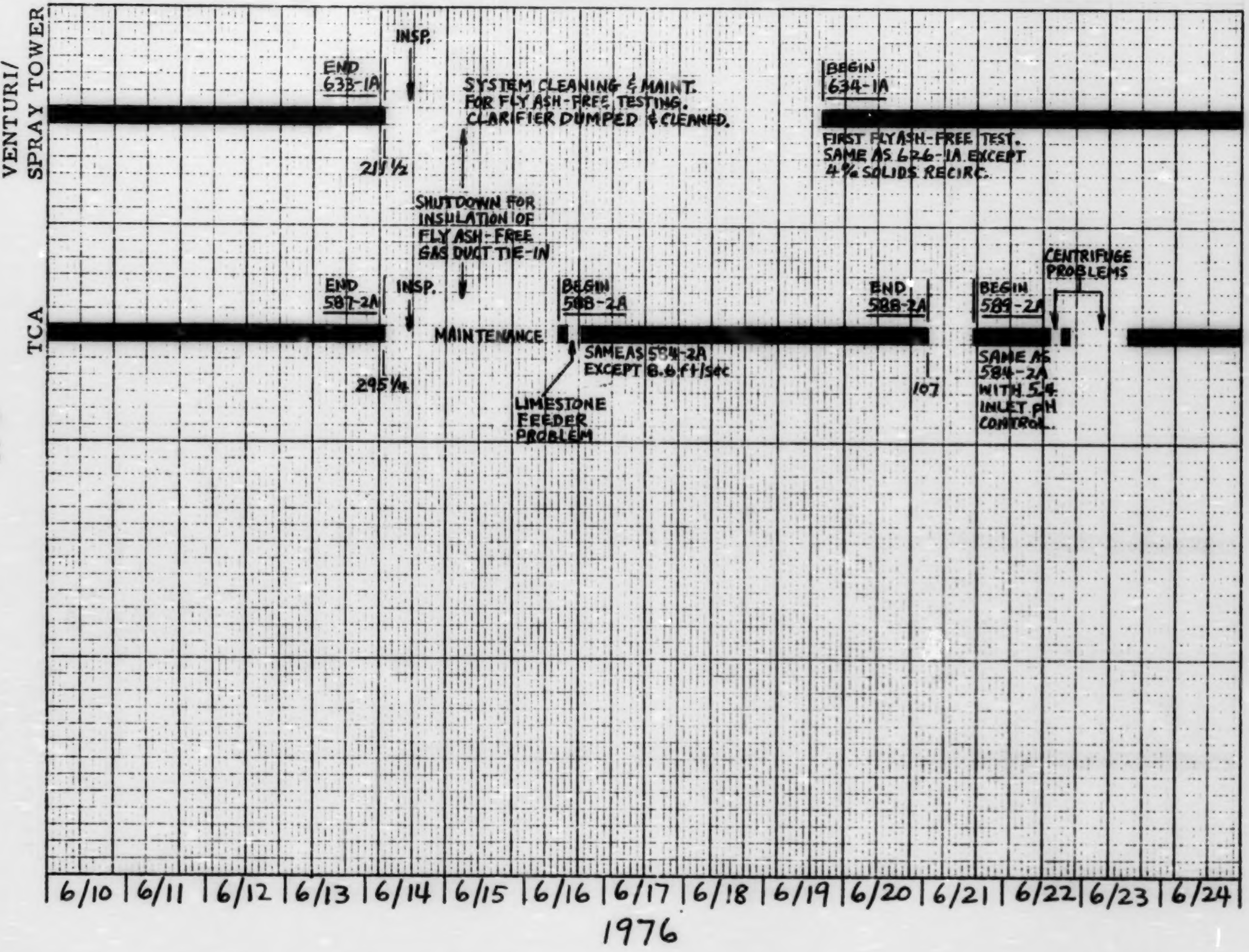

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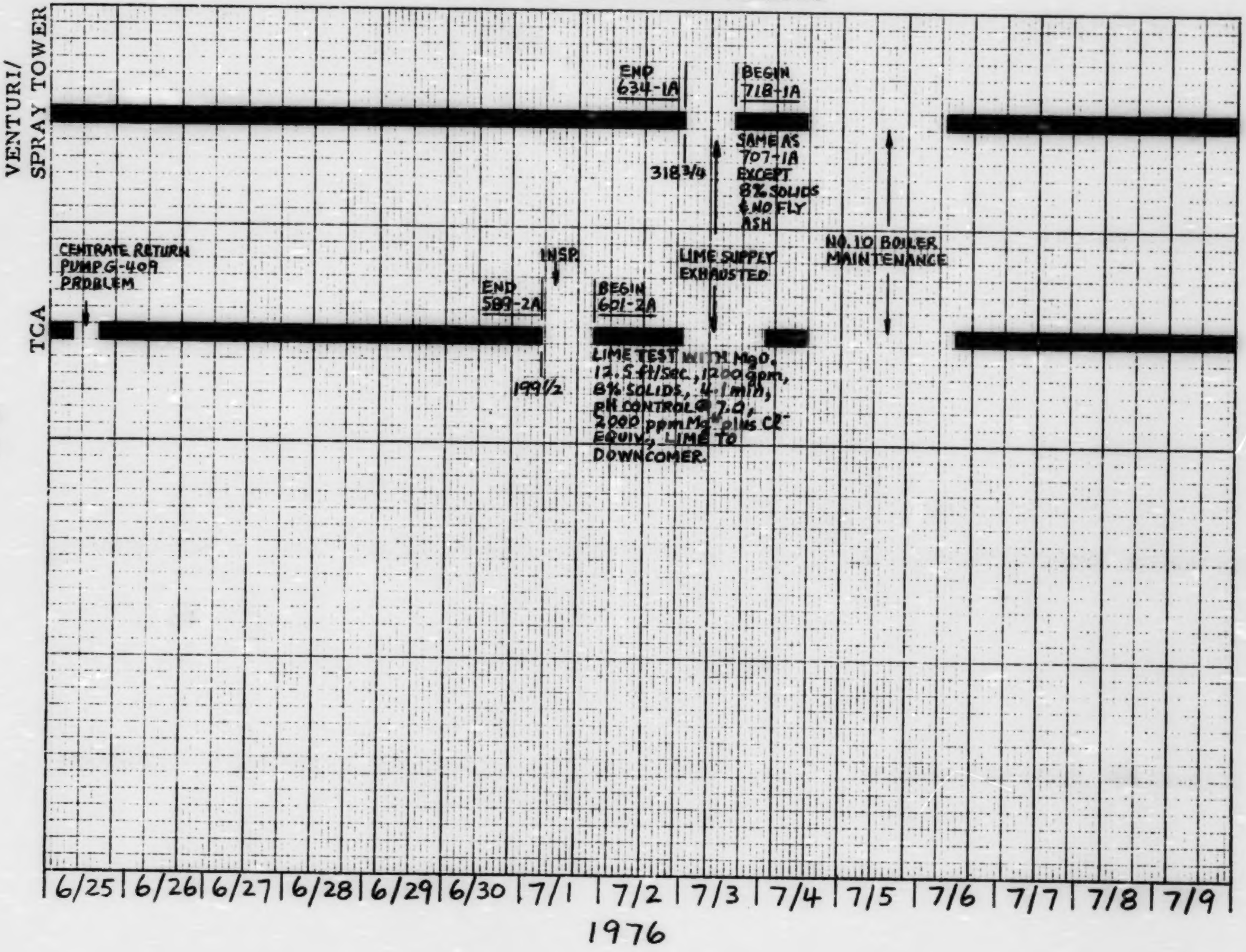

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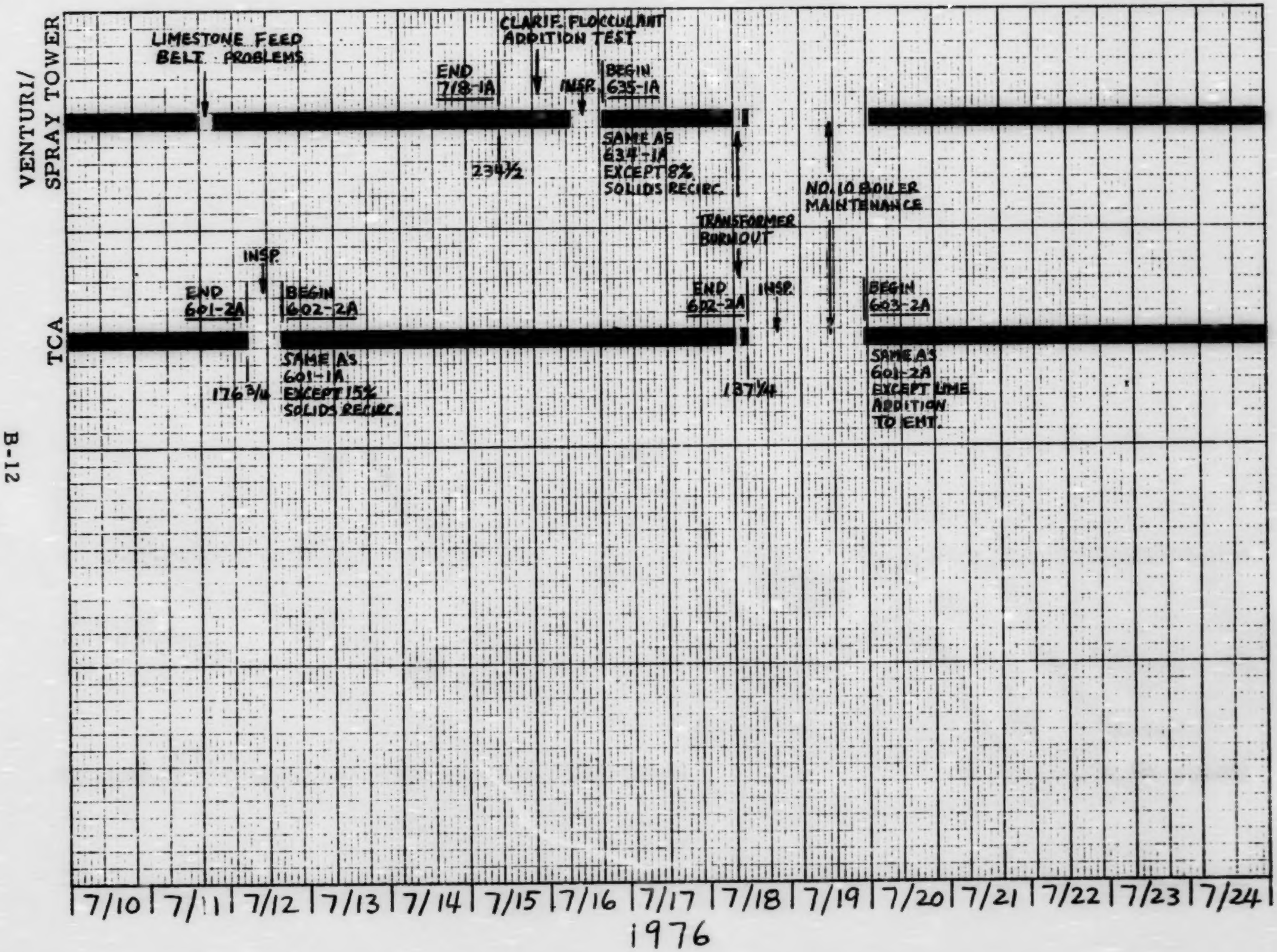

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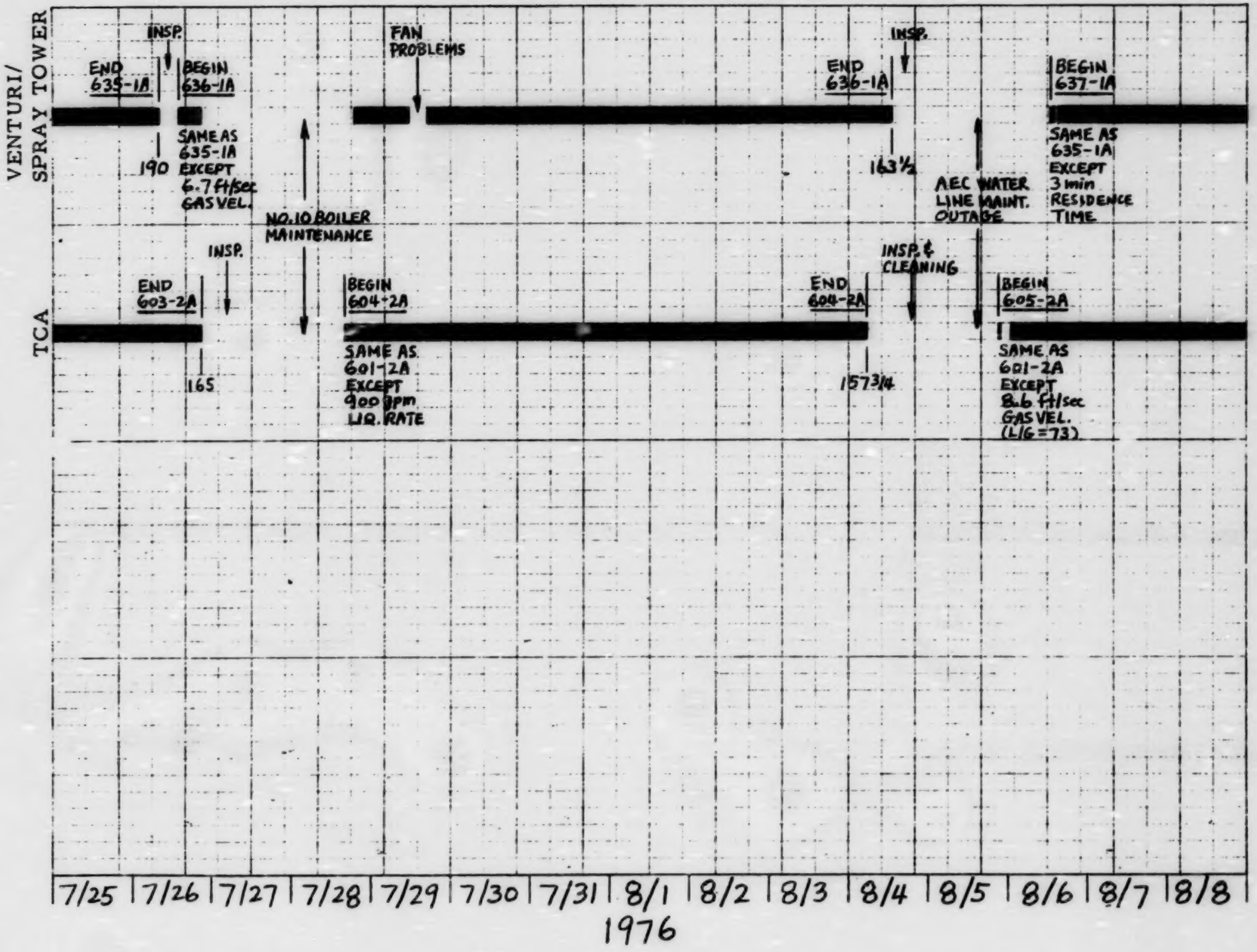

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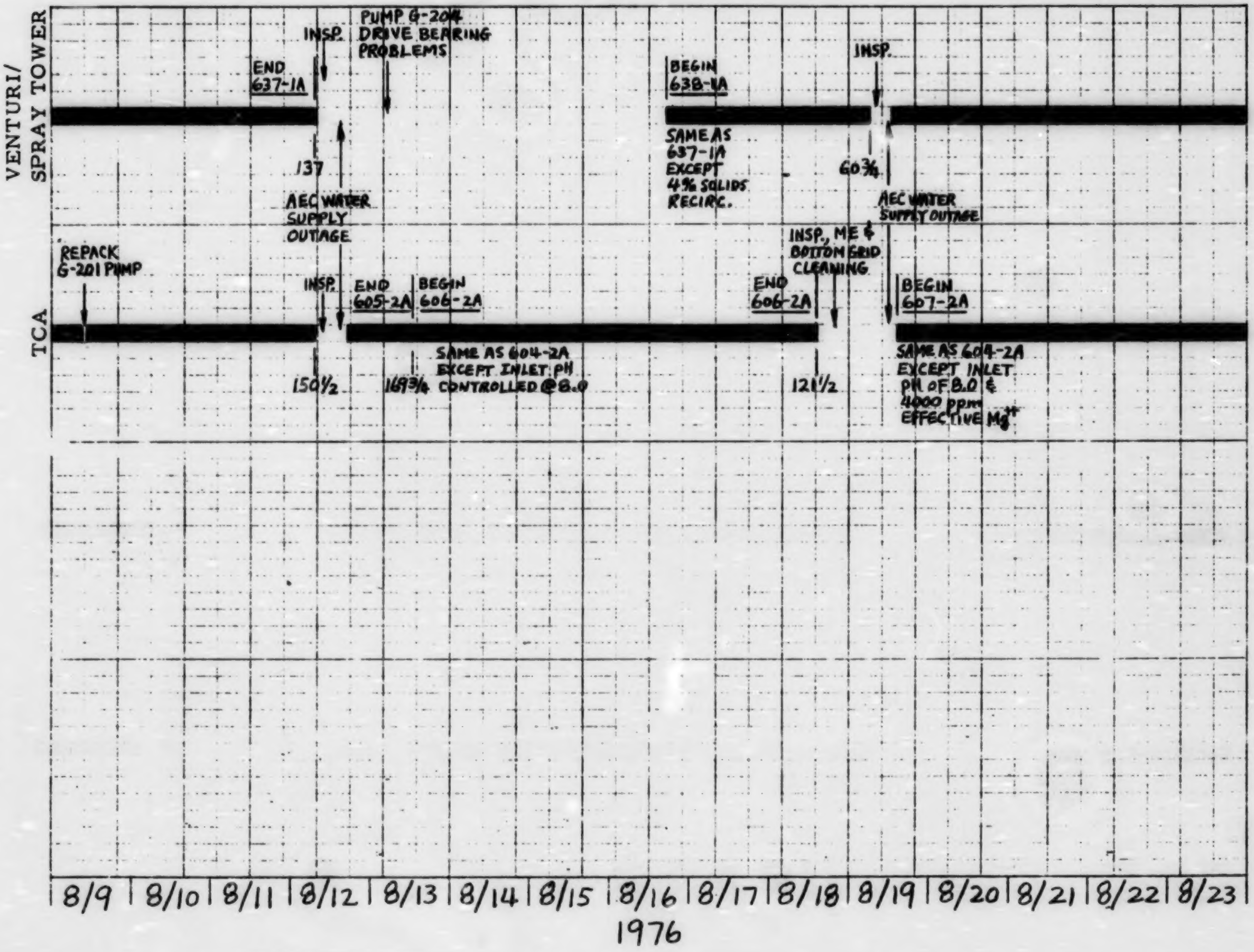

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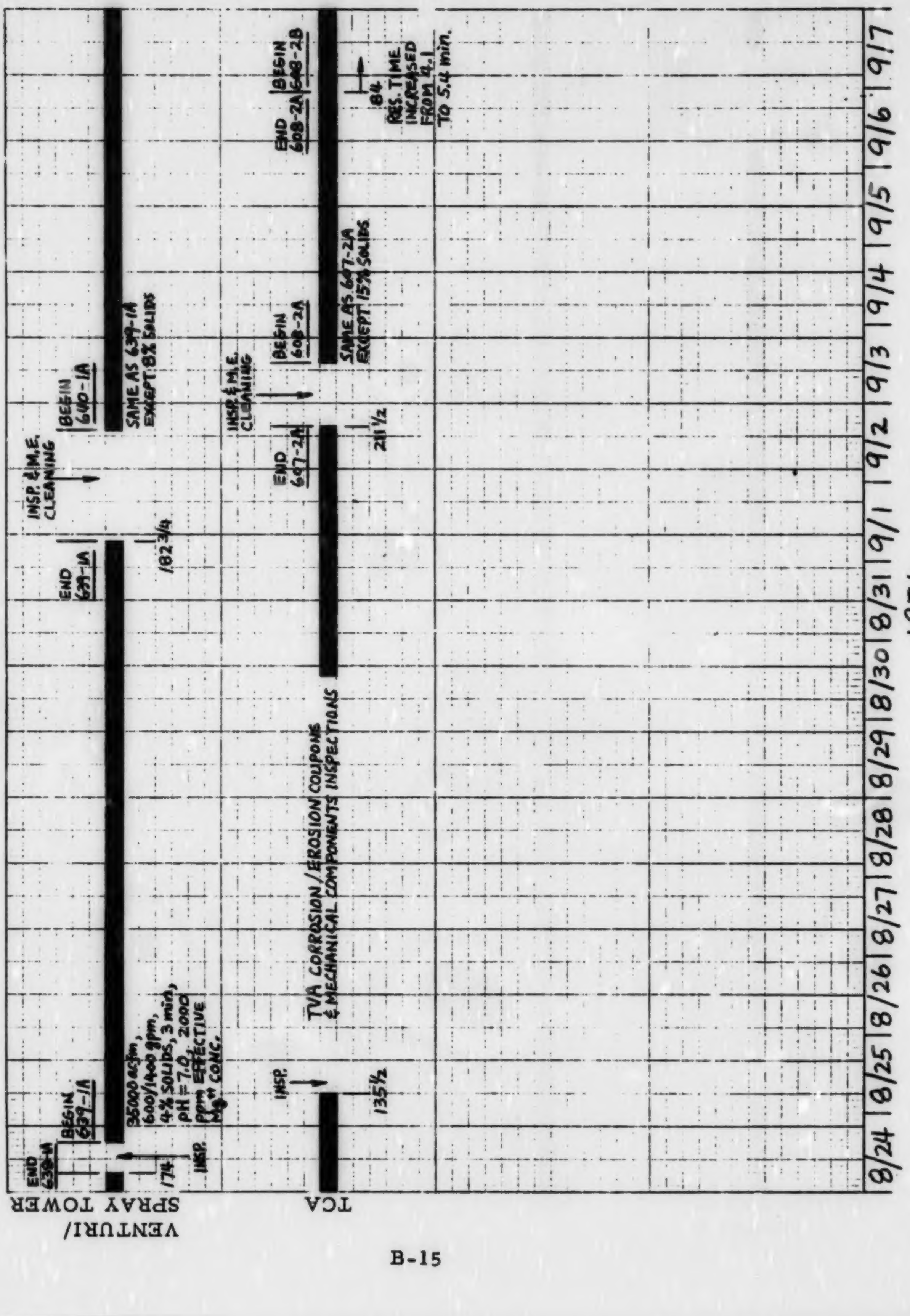

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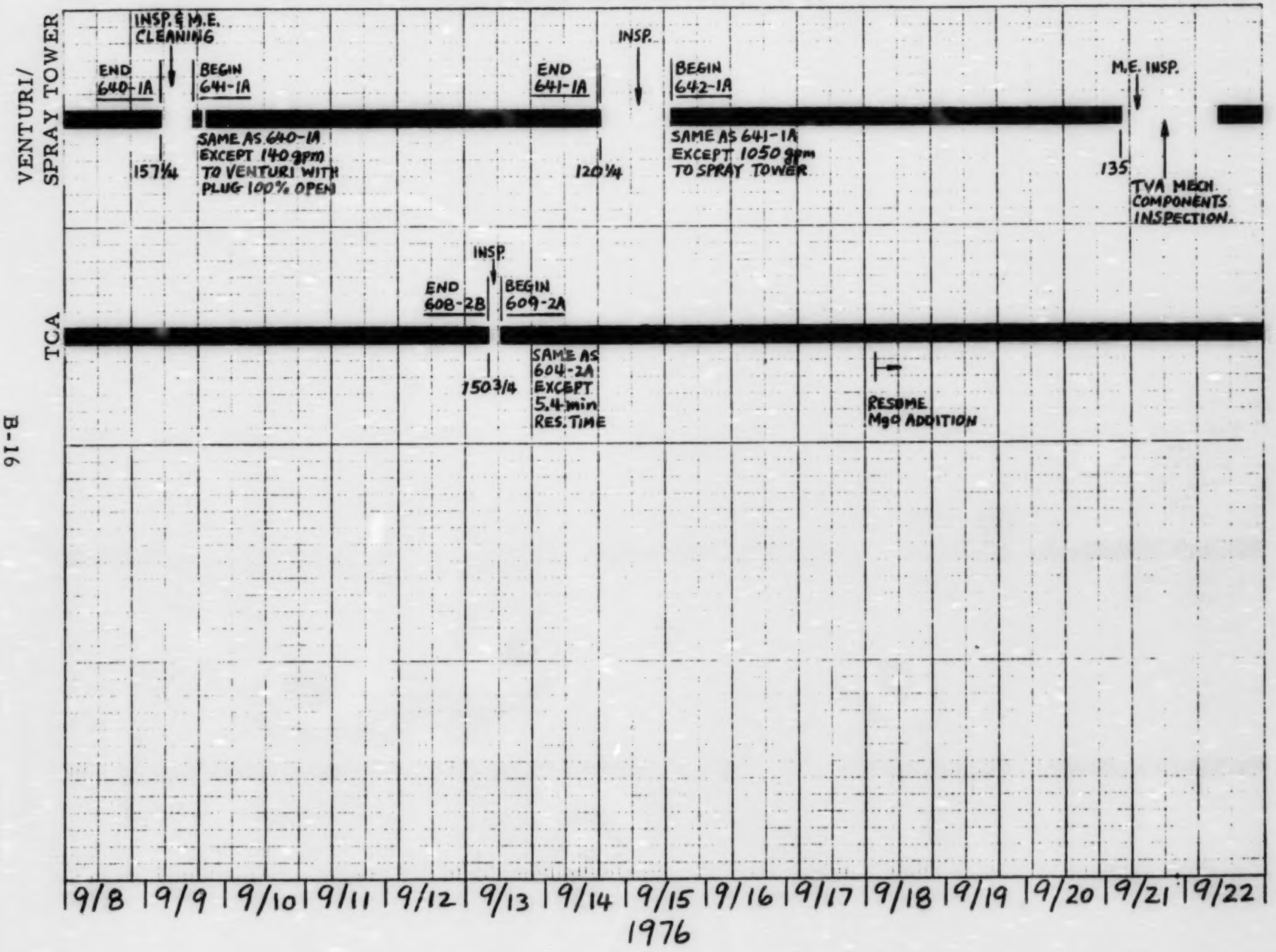

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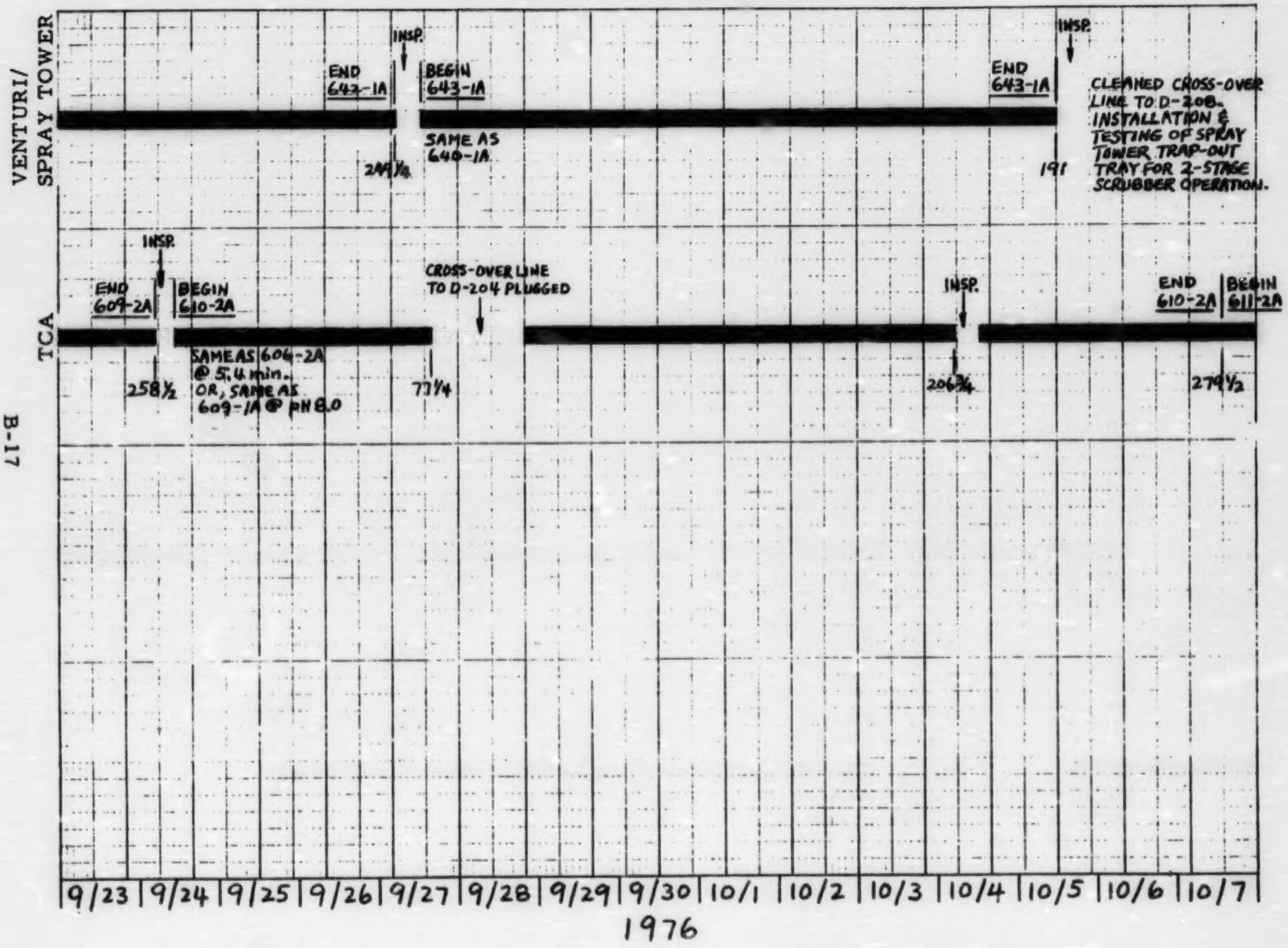

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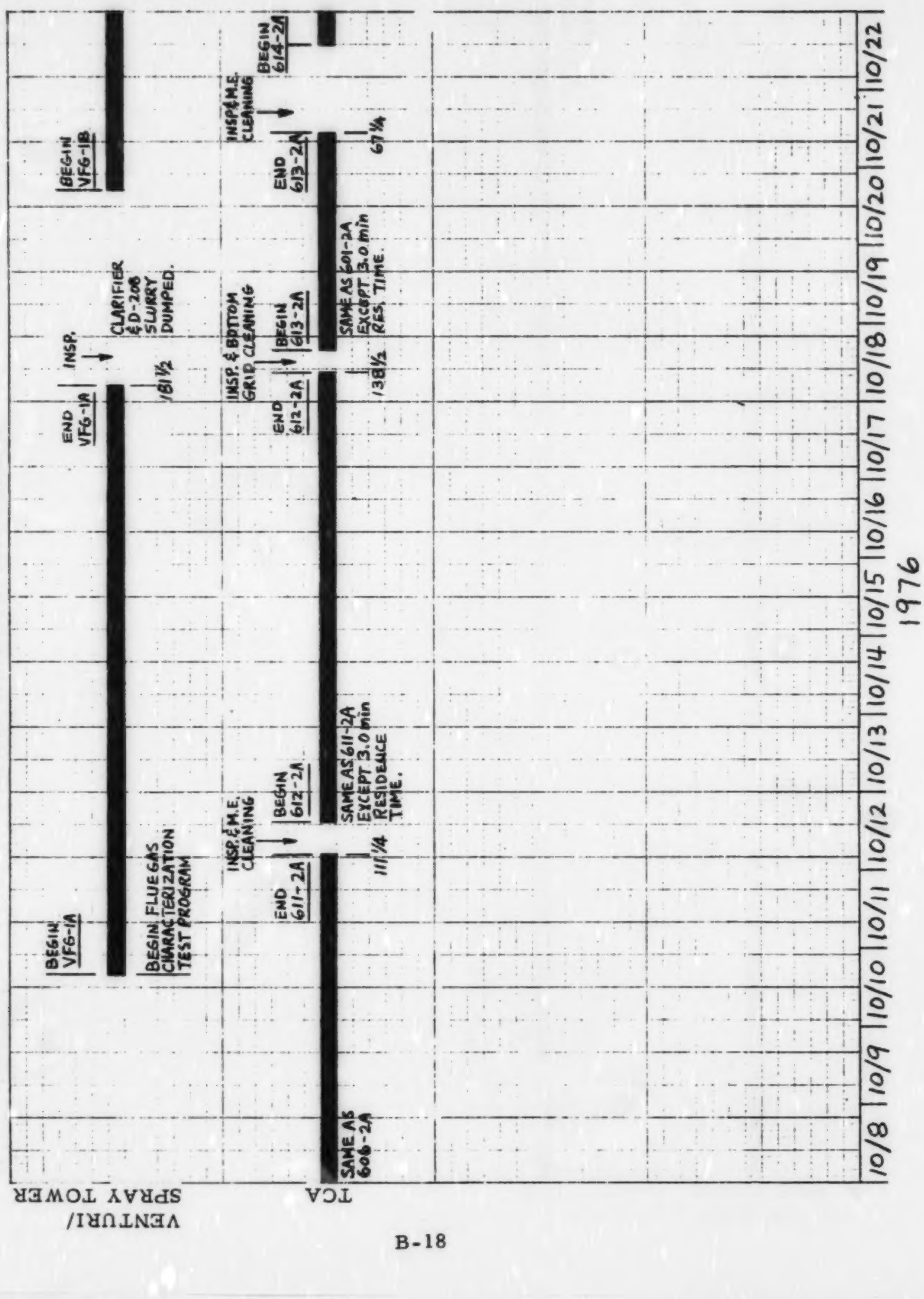

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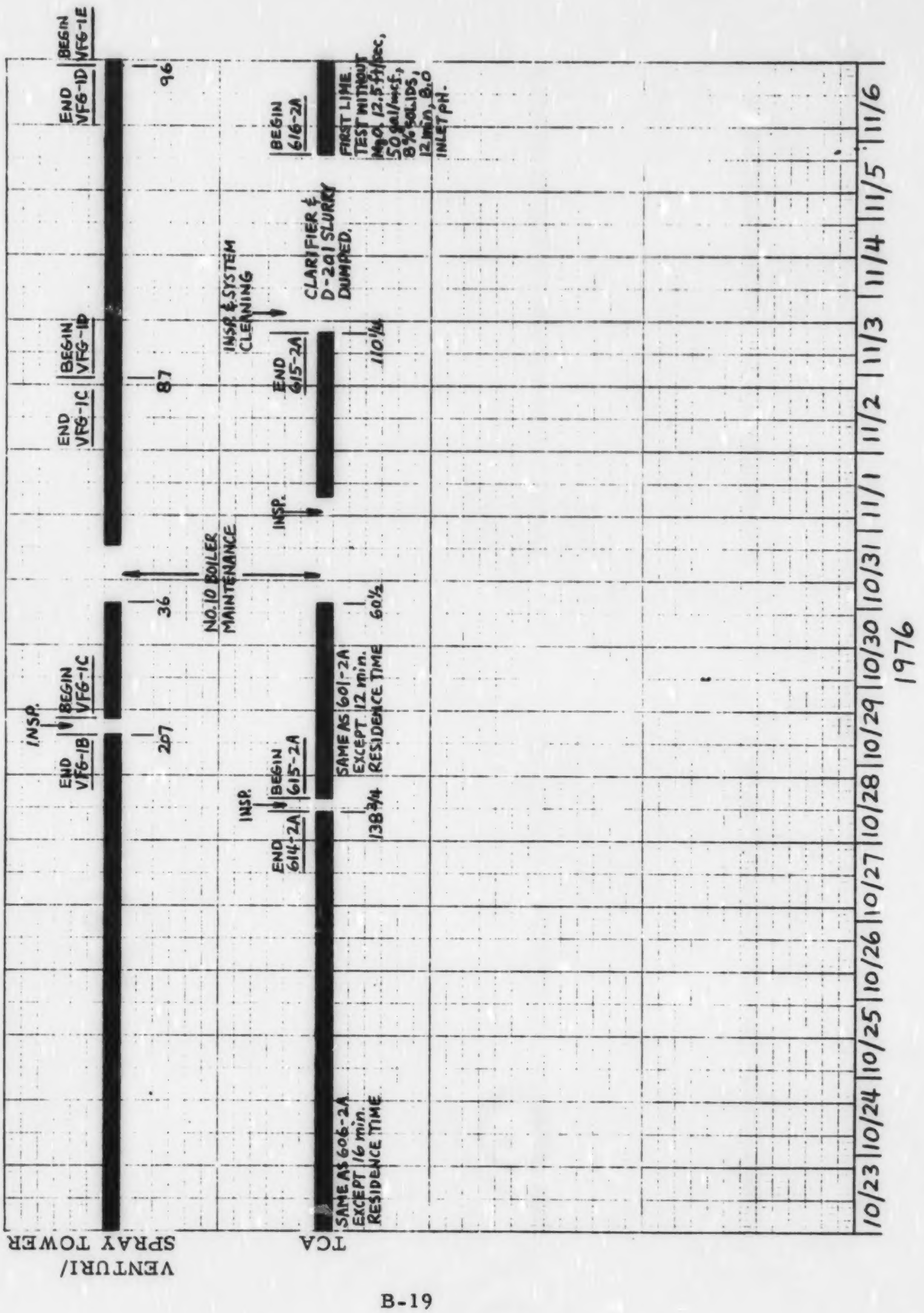

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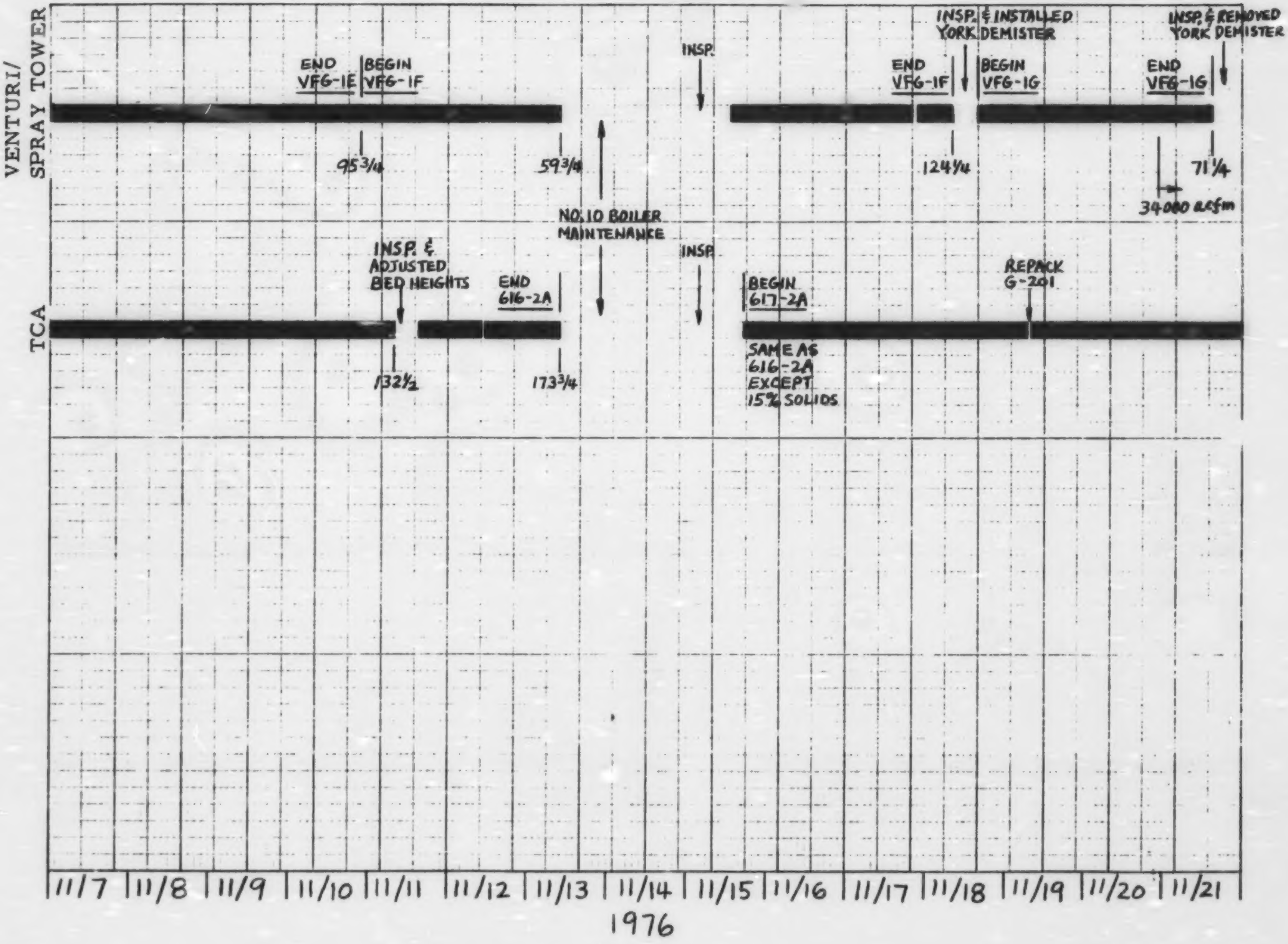

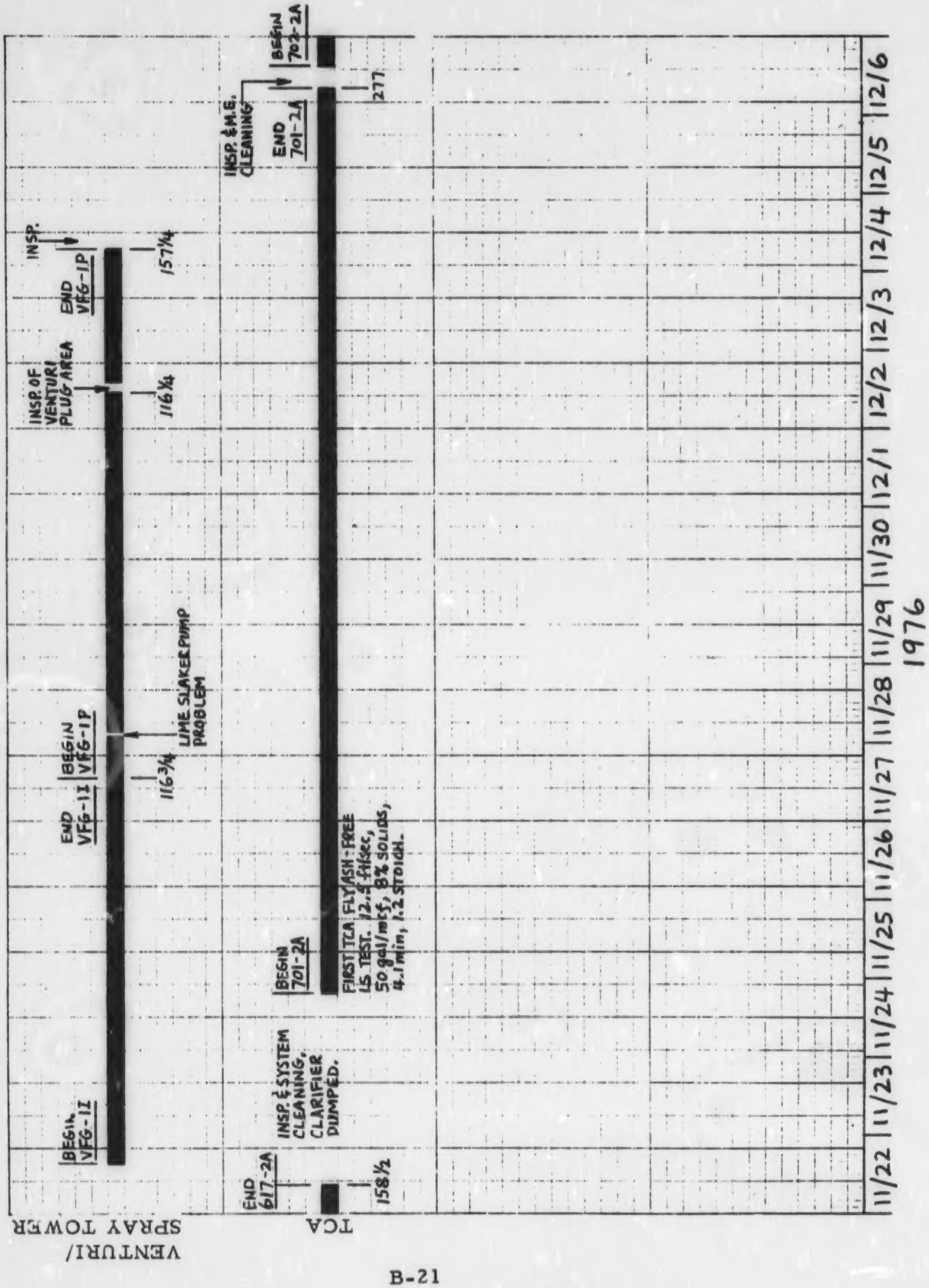

SCRUBBER OPERATING PERIODS

APPENDIX C

PROPERTIES OF RAW MATERIALS

The following is a summary of the properties of the raw materials used from mid-February 1976 through November 1976.

C.1 COAL

Supplier: Several

Type: Eastern (Southern Illinois) high sulfur.

Analysis:

9.4	to	12.4	wt % total moisture
2.3	to	5.5	wt % sulfur
0.03	to	0.27	wt % chloride
13.0	to	16.3	wt % ash

Approximate Ash Analysis:

54 wt % SiO_2
23 wt % Al_2O_3
12 wt % Fe_2O_3
3 wt % CaO
1 wt % MgO
1 wt % SO_3
3 wt % K_2O
1 wt % Na_2O
3 wt % Ignition loss

C.2 LIMESTONE

Supplier:	Fredonia Quarries, Fredonia, Kentucky	
Type:	Fredonia Valley White	
Analysis:	95	wt % $CaCO_3$
	1	wt % $MgCO_3$
	4	wt % Inerts
Grind:	91	wt % less than 325 mesh
	87	wt % less than 30 microns
	86	wt % less than 27 microns
	53	wt % less than 6 microns

C.3 LIME

Supplier:	Linwood Stone Co., Davenport, Iowa (through 9/75) Mississippi Lime Co., Alton, Illinois (after 9/75)	
Type:	Pebble lime, unslaked	
Analysis:	97.0	wt % CaO total
	95.5	wt % CaO available
	0.28	wt % MgO
	0.47	wt % Inerts

C.4 MAGNESIUM OXIDE

Supplier:	Basic Chemicals, Ft. St. Joe, Florida	
Type:	MAGOX PG (pollution grade)	
Analysis:	97.6	wt % MgO
	1.5	wt % CaO
	0.5	wt % SiO_2
	0.4	wt % R_2O_3

APPENDIX D

DATABASE TABLES

The NOMAD database system can be used to print reports of selected data. All the data for the period of this report (February 12, 1976, to December 4, 1976, for the venturi/spray tower system and February 12, 1976, to December 1976, for the TCA system) are given below.

The following codes and abbreviations are used in the database tables:

Operating Conditions and Systems Configuration

(Pages D-5 and D-6 for the venturi/spray tower system and pages D-87 and D-88 for the TCA system)

Alkali Type
L = lime addition
LS = limestone addition

Fly Ash and MgO Addition
Y = yes
N = no

Spray Tower Header Configuration
1 = spray nozzle bank 1 (the lowest) on
2 = spray nozzle bank 2 (second lowest) on
3 = spray nozzle bank 3 (second from top) on
4 = spray nozzle bank 4 (top header) on

Mist Eliminator System Configuration
1-3P/OV = one three-pass, open-vane mist eliminator installed
CHE+YRK = one three-pass, open vane chevron plus one York mist eliminator installed (see Section 8)

Mist Eliminator Wash, Bottom/Top
I = intermittent wash (see appropriate Summary Table for details)
C = continuous wash

Dewatering System
    CL = clarifier used for thickening solids for disposal
    CE = centrifuge used
    F = vacuum drum filter used
    i.e. CL/CE = clarifier and centrifuge used in series

Alkali Addition Point
    DNC = alkali added to scrubber downcomer (scrubber outlet) before slurry enters the effluent hold tank
    EHT = alkali added to effluent hold tank

TCA Total Bed Height = height in inches for 3 beds
TCA Sphere Type
    FOAM = solid nitrile foam spheres used in TCA beds

Analytical Data

(Summary begins on page D-7 and listing begins on page D-21 for the venturi/spray tower; summary begins on page D-89 and listing begins on page D-103 for the TCA. Analytical data are presented in the order of gas, liquid and solids for both the summary and listings.)

Analytical Point
    1815 = inlet to venturi (not measured during this reporting period)
    1816 = inlet to spray tower
    1825 = outlet from spray tower
    1851 = outlet from venturi (not measured)
    2816 = inlet to TCA scrubber
    2825 = outlet from TCA scrubber
    2831 = inlet to Penberthy air eductor (not measured)

Flags for Analytical Data

Three flag fields (one each for gas, liquid, and solids data) have been put in the database to allow questionable or non-representative data to be marked. Non-representative data includes data taken at start-up or during upset operating conditions.

Gas Flag

X = all gas data taken at this time is questionable
N = all gas data is non-representative
I = SO_2 inlet concentration questionable
O = SO_2 outlet concentration questionable
A = O_2 inlet concentration questionable

The gas flag field contains a maximum of two characters.

Liquid Flag

X = all liquid data taken at this time is questionable
N = all liquor data is non-representative
PH = pH value questionable
CA = liquor Ca^{++} concentration questionable
MG = liquor Mg^{++} concentration questionable
NA = liquor Na^{+} concentration questionable
K = liquor K^{+} concentration questionable
SO3 = liquor $SO_3^{=}$ concentration questionable
TS = liquor total S (as $SO_4^{=}$) concentration questionable
CL = liquor Cl^{-} concentration questionable

The liquid and solids fields have a maximum of seven characters. When more than three suspect values occur, X is placed in the flag field.

Solid Flag

X = all solid data taken at this time is questionable
N = all solid data is non-representative
CA = solid CaO concentration questionable
SO2 = solid SO_3 (as SO_2) concentration questionable
TS = solid total S (as SO_3) concentration questionable
CO2 = solid CO_3 (as CO_2) concentration questionable
SS = solids concentration in slurry questionable
AI = acid insoluble solids concentration questionable

Flue Gas Characterization

Data collected for Runs VFG-1A through VFG-1P begins on page D-75. For discussion see Section 8.

VST OPERATING CONDITIONS

RUN NO.	ALK TYPE	FLY ASH	MGO	PH CONTR POINT	GAS RATE ACFM	GAS VEL FPS	VEN LIQ RATE GPM	S.T. LIQ RATE GPM	VEN L/G GAL/MACF	S.T. L/G GAL/MACF	EFFLU RES TIME MIN	SOLID RECIRC NOM %	SOLIDS DISCH RANGE %	VEN D.P. IN. H2O	S.T. D.P. IN. H2O	M.E.SYSTEM D.P.RANGE IN.H2O	RUN NO.
629-1A	L	Y	Y	6.00	35000	9.4	600	1400	21.4	49.8	3.0	8.0	52-60	9.0	4.6	0.40-0.55	629-1A
630-1A	L	Y	Y	7.00	35000	9.4	600	1400	21.4	49.8	3.0	8.0	50-56	9.0	4.4	0.40-0.50	630-1A
631-1A	L	Y	Y	7.00	35000	9.4	600	700	21.4	24.9	3.0	8.0	53-59	9.0	4.5	0.40-0.48	631-1A
632-1A	L	Y	Y	7.00	35000	9.4	140	1400	5.0	49.8	3.0	8.0	52-56	2.8	4.3	0.40-0.45	632-1A
633-1A	L	Y	Y	7.00	25000	6.7	140	1400	7.0	69.8	3.0	8.0	49-53	1.8	2.1	0.21-0.24	633-1A
634-1A	L	N	N	8.00	35000	9.4	600	1400	21.4	49.8	12.0	4.0	51-65	9.0	4.0	0.46-0.51	634-1A
635-1A	L	N	N	8.00	35000	9.4	600	1400	21.4	49.8	12.0	8.5	42-52	9.0	4.3	0.46-0.51	635-1A
636-1A	L	N	N	8.00	25000	6.7	600	1400	29.9	69.8	12.0	8.0	42-46	9.0	2.0	0.23-0.26	636-1A
637-1A	L	N	N	8.00	35000	9.4	600	1400	21.4	49.8	3.0	8.0	44-50	9.0	4.0	0.45-0.48	637-1A
638-1A	L	N	N	8.00	35000	9.4	600	1400	21.4	49.8	3.0	4.0	47-59	9.0	3.7	0.45-0.48	638-1A
639-1A	L	N	Y	7.00	35000	9.4	600	1400	21.4	49.8	3.0	4.0	44-54	9.0	4.2	0.47-0.59	639-1A
640-1A	L	N	Y	7.00	35000	9.4	600	1400	21.4	49.8	3.0	8.0	48-51	9.0	4.5	0.45-0.52	640-1A
641-1A	L	N	Y	7.00	35000	9.4	140	1400	5.0	49.8	3.0	8.0	45-50	3.6	3.2	0.48-0.51	641-1A
642-1A	L	N	Y	7.00	35000	9.4	140	1050	5.0	37.4	3.0	8.0	45-57	3.5	3.5	0.48-0.51	642-1A
643-1A	L	N	Y	7.00	35000	9.4	600	1400	21.4	49.8	3.0	8.0	41-46	9.0	4.0	0.41-0.48	643-1A
VFG-1A	L	Y	Y	7.00	35000	9.4	600	1400	21.4	49.8	3.0	8.0	48-57	9.0	4.0	0.44-0.49	VFG-1A
VFG-1B	L	N	N	8.00	35000	9.4	600	1400	21.4	49.8	12.0	8.0	42-62	9.0	4.3	0.45-0.50	VFG-1B
VFG-1C	L	Y	N	8.00	35000	9.4	600	1400	21.4	49.8	12.0	8.0	53-60	9.0	4.5	0.45-0.50	VFG-1C
VFG-1D	L	Y	N	8.00	20000	5.4	600	1400	37.4	87.2	12.0	8.0	51-57	9.0	1.4	0.11-0.15	VFG-1D
VFG-1E	L	Y	N	8.00	35000	9.4	375	1400	13.4	49.8	12.0	8.0	45-63	5.3	4.2	0.43-0.50	VFG-1E
VFG-1F	L	Y	N	8.00	35000	9.4	600	0	21.4	0.0	20.0	8.0	59-64	9.0	3.5	0.37-0.45	VFG-1F
VFG-1G	L	Y	N	8.00	35000	9.4	600	1400	21.4	49.8	12.0	8.0	51-54	9.0	4.6	0.79-1.75	VFG-1G
VFG-1I	L	Y	N	8.00	35000	9.4	600	1400	21.4	49.8	12.0	15.0	52-55	9.0	4.5	0.38-0.44	VFG-1I
VFG-1P	L	Y	N	8.00	35000	9.4	140	1400	5.0	49.8	12.0	8.0	55-60	3.6	3.9	0.35-0.42	VFG-1P

VST RUN DEFINITION AND SYSTEM CONFIGURATION

RUN NO.	START DATE	START TIME	END DATE	END TIME	HOURS ON STRM	S.T. HEADER CONFIG	NO.OF HOLD TANKS	M.E. SYSTEM CONFIG	M.E. WASH B/T	DE-WATER SYSTEM	ALK ADDN PT.	RUN NO.
629-1A	04/28/76	1800	05/12/76	0800	266	1234	1	1-3P/OV	I/I	CL/F	DNC	629-1A
630-1A	05/12/76	1000	05/18/76	0800	142	1234	1	1-3P/OV	I/I	CL/F	DNC	630-1A
631-1A	05/18/76	1145	05/24/76	1345	145	34	1	1-3P/OV	I/I	CL/F	DNC	631-1A
632-1A	05/28/76	1815	06/04/76	0245	151	1234	1	1-3P/OV	I/I	CL/F	DNC	632-1A
633-1A	06/05/76	1000	06/14/76	0530	212	1234	1	1-3P/OV	I/I	CL/F	DNC	633-1A
634-1A	06/19/76	1700	07/02/76	2345	319	1234	1	1-3P/OV	I/I	CL/F	DNC	634-1A
635-1A	07/16/76	1710	07/26/76	0813	190	1234	1	1-3P/OV	I/I	CL/F	DNC	635-1A
636-1A	07/28/76	1830	08/04/76	1256	164	1234	1	1-3P/OV	I/I	CL/F	DNC	636-1A
637-1A	08/06/76	1315	08/12/76	0735	137	1234	1	1-3P/OV	I/I	CL/F	DNC	637-1A
638-1A	08/17/76	1726	08/24/76	0547	174	1234	1	1-3P/OV	I/I	CL/F	DNC	638-1A
639-1A	08/24/76	1455	09/01/76	0550	183	1234	1	1-3P/OV	I/I	CL/F	DNC	639-1A
640-1A	09/02/76	1555	09/09/76	0515	157	1234	1	1-3P/OV	I/I	CL/F	DNC	640-1A
641-1A	09/09/76	1430	09/14/76	1656	120	1234	1	1-3P/OV	I/I	CL/F	DNC	641-1A
642-1A	09/15/76	1430	09/27/76	0525	249	1 34	1	1-3P/OV	I/I	CL/F	DNC	642-1A
643-1A	09/27/76	1250	10/05/76	1203	191	1234	1	1-3P/OV	I/I	CL/CE	DNC	643-1A
VFG-1A	10/10/76	1550	10/18/76	0530	182	1234	1	1-3P/OV	I/I	CL/F	DNC	VFG-1A
VFG-1B	10/20/76	1734	10/29/76	0830	207	1234	1	1-3P/OV	I/I	CL/F	DNC	VFG-1B
VFG-1C	10/29/76	1330	11/02/76	2215	87	1234	1	1-3P/OV	I/I	CL/F	DNC	VFG-1C
VFG-1D	11/02/76	2215	11/06/76	2215	96	1234	1	1-3P/OV	I/I	CL/F	DNC	VFG-1D
VFG-1E	11/06/76	2215	11/10/76	2200	96	1234	1	1-3P/OV	I/I	CL/F	DNC	VFG-1E
VFG-1F	11/10/76	2200	11/18/76	0815	124	NONE	1	1-3P/OV	I/I	CL/F	DNC	VFG-1F
VFG-1G	11/18/76	1600	11/21/76	1518	71	1234	1	CHE+YRK	I/I	CL/F	DNC	VFG-1G
VFG-1I	11/22/76	1530	11/27/76	1300	117	1234	1	1-3P/OV	I/I	CL/F	DNC	VFG-1I
VFG-1P	11/27/76	1305	12/04/76	0715	157	1234	1	1-3P/OV	I/I	CL/F	DNC	VFG-1P

VST ANALYTICAL RUN SUMMARY (GASES)

RUN NO.	AVG SO2 IN PPM	MINIMUM SO2 IN PPM	MAXIMUM SO2 IN PPM	AVG SO2 OUT PPM	MINIMUM SO2 OUT PPM	MAXIMUM SO2 OUT PPM	AVG SO2 REM %	MINIMUM SO2 REM %	MAXIMUM SO2 REM %	AVG MAKE PER PASS MMOL/L	MINIMUM MAKE PER PASS MMOL/L	MAXIMUM MAKE PER PASS MMOL/L	RUN NO.
629-1A	3244	2320	4280	625	180	1050	78	69	95	9.5	7.0	13.2	629-1A
630-1A	3101	2120	3880	219	50	440	91	85	99	10.6	7.1	14.1	630-1A
631-1A	2920	2240	3920	753	200	1600	71	55	93	11.9	9.7	17.4	631-1A
632-1A	2766	2040	3360	481	140	1020	80	64	93	10.8	8.7	13.0	632-1A
633-1A	2993	2200	3600	219	60	560	91	82	98	9.5	6.9	11.0	633-1A
634-1A	2517	1480	3760	558	220	1020	76	68	85	7.0	4.6	9.7	634-1A
635-1A	2602	1700	3600	512	130	1300	79	60	92	7.5	5.8	8.9	635-1A
636-1A	2955	2320	3560	412	220	740	84	77	89	6.6	5.5	7.8	636-1A
637-1A	2998	2680	3520	792	540	1040	70	66	78	7.9	7.3	8.8	637-1A
638-1A	2604	2000	3100	523	220	760	78	73	88	7.5	6.3	8.4	638-1A
639-1A	2688	2080	3200	346	0	800	86	72	100	8.5	6.9	10.3	639-1A
640-1A	2972	2560	3600	560	320	830	79	74	86	8.7	7.9	11.0	640-1A
641-1A	2647	2200	3000	293	80	800	87	69	97	11.2	8.1	13.7	641-1A
642-1A	2597	2200	3240	706	120	1020	70	61	94	11.3	9.4	16.3	642-1A
643-1A	2556	2000	2920	64	20	320	97	88	99	9.2	7.2	10.6	643-1A
VFG-1A	3044	2560	3560	204	40	900	92	67	95	10.5	7.4	13.0	VFG-1A
VFG-1B	2951	2520	3520	709	540	1000	73	68	76	8.0	7.1	9.2	VFG-1B
VFG-1C	2916	2520	3360	738	520	1000	71	67	78	7.8	7.0	8.8	VFG-1C
VFG-1D	3206	2800	3680	324	120	940	88	66	95	6.0	4.3	7.2	VFG-1D
VFG-1E	3168	2760	3600	784	440	1140	72	65	85	9.6	8.1	11.2	VFG-1E
VFG-1F	3329	2400	3840	2233	1520	2760	25	20	48	10.3	8.7	21.7	VFG-1F
VFG-1G	3042	2080	3400	475	100	620	83	79	95	9.3	7.3	10.1	VFG-1G
VFG-1I	3112	2600	3720	600	380	900	78	70	85	9.1	7.9	10.5	VFG-1I
VFG-1P	3184	2400	3880	1019	680	1540	64	56	70	9.9	7.9	11.1	VFG-1P

VST ANALYTICAL RUN SUMMARY (GASES) - CONTINUED

RUN NO.	AVG O2 IN %	MINIMUM O2 IN %	MAXIMUM O2 IN %	AVG BOIL LOAD MEGA WATT	MINIMUM BOIL LOAD MEGA WATT	MAXIMUM BOIL LOAD MEGA WATT	RUN NO.
629-1A							629-1A
630-1A							630-1A
631-1A							631-1A
632-1A							632-1A
633-1A							633-1A
634-1A							634-1A
635-1A							635-1A
636-1A	8.7	7.8	9.5	139	113	149	636-1A
637-1A	7.5	6.0	9.0	144	128	148	637-1A
638-1A	8.0	6.3	10.5	140	100	150	638-1A
639-1A	8.3	6.4	9.2	139	103	148	639-1A
640-1A	7.9	6.5	10.2	134	105	148	640-1A
641-1A	9.5	6.0	10.2	136	100	163	641-1A
642-1A	8.1	4.2	12.5	142	115	149	642-1A
643-1A	8.6	6.2	10.0	139	110	148	643-1A
VFG-1A	5.6	3.6	8.5	139	100	150	VFG-1A
VFG-1B	8.9	7.0	12.8	142	114	150	VFG-1B
VFG-1C	6.0	4.4	11.5	149	138	156	VFG-1C
VFG-1D	5.6	4.0	6.7	138	94	156	VFG-1D
VFG-1E	6.3	4.3	10.2	141	80	156	VFG-1E
VFG-1F	5.8	4.7	8.1	152	142	155	VFG-1F
VFG-1G	5.1	4.2	5.6	140	101	153	VFG-1G
VFG-1I	5.1	3.4	7.0	143	101	152	VFG-1I
VFG-1P	5.8	3.8	7.5	141	90	150	VFG-1P

RUN SUMMARY - LIQUID ANALYTICAL DATA

CONCENTRATIONS IN LIQUID, PPM

RUN NO.	ANALYTICAL POINT	PH			CA++			MG++			SO3=			SO4=			CL-		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
629-1A	1815																		
	1816	5.98	5.64	6.15	644	223	924	3771	2809	5349	849	90	2216	9763	6803	13619	3887	3013	5140
	1825																		
	1851																		
630-1A	1815																		
	1816	6.94	6.17	7.12	268	106	600	3923	3179	4949	633	180	1492	7610	5910	10220	5636	4609	6381
	1825																		
	1851																		
631-1A	1815																		
	1816	6.98	6.79	7.12	585	106	1182	4560	3539	5889	482	113	1221	8102	5806	9446	7428	5672	9218
	1825																		
	1851																		
632-1A	1815																		
	1816	6.98	6.45	7.36	229	141	461	4589	4009	5459	783	316	1402	7252	5543	8193	7119	6381	8509
	1825																		
	1851																		
633-1A	1815																		
	1816	7.03	6.86	7.28	177	83	569	4067	3579	4649	1124	271	2103	8205	6055	9496	5051	4431	5850
	1825																		
	1851																		
634-1A	1815																		
	1816	8.01	7.66	8.16	1950	1356	2530	332	28	587	66	13	226	1370	261	2994	3408	1950	4343
	1825																		
	1851																		
635-1A	1815																		
	1816	8.02	6.32	8.65	2260	1890	2679	639	515	753	97	36	226	1494	339	2442	4627	4077	5300
	1825																		
	1851																		
636-1A	1815																		
	1816	8.01	7.79	8.24	2140	1490	2690	650	597	689	75	22	226	1422	499	2072	4282	3545	4963
	1825																		
	1851																		
637-1A	1815																		
	1816	7.92	6.57	8.79	1612	1200	1975	604	539	700	92	22	316	1469	1125	1740	3368	2747	3722
	1825																		
	1851																		
638-1A	1815																		
	1816	7.95	7.69	8.20	2008	1400	2380	609	491	751	119	22	226	1995	1386	2391	3616	2925	4077
	1825																		
	1851																		

RUN SUMMARY - LIQUID ANALYTICAL DATA (CONTINUED)

RUN NC.	ANALYTICAL POINT	TOTAL IONS, PPM			PERCENT SULFATE SATURATION			PERCENT IONIC IMBALANCE		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
629-1A	1815									
	1816	19046	15517	24621	76	28	114	3.3	-8.5	12.2
	1825									
	1851									
630-1A	1815									
	1816	18238	15864	20750	27	11	77	1.7	-15.3	19.7
	1825									
	1851									
631-1A	1815									
	1816	21287	16491	25544	53	9	110	4.4	-8.6	11.4
	1825									
	1851									
632-1A	1815									
	1816	20115	18721	22450	19	9	41	5.4	-3.0	15.6
	1825									
	1851									
633-1A	1815									
	1816	18763	16992	20703	18	7	60	1.6	-14.4	11.4
	1825									
	1851									
634-1A	1815									
	1816	7157	4301	9836	93	18	184	-1.1	-18.9	17.3
	1825									
	1851									
635-1A	1815									
	1816	9162	7567	10476	91	21	148	1.6	-9.2	11.9
	1825									
	1851									
636-1A	1815									
	1816	8613	6689	10045	86	27	132	5.7	-1.0	16.9
	1825									
	1851									
637-1A	1815									
	1816	7180	5888	8190	79	59	102	2.4	-7.6	8.7
	1825									
	1851									
638-1A	1815									
	1816	8383	6457	9091	115	76	138	2.8	-6.5	14.3
	1825									
	1851									

ANALYTICAL DATA SUMMARY RUN REPORT
WEDNESDAY THE 21ST OF SEPTEMBER 1977

RUN SUMMARY - LIQUID ANALYTICAL DATA

CONCENTRATIONS IN LIQUID, PPM

RUN NO.	ANALYTICAL POINT	PH			CA++			MG++			SO3=			SO4=			CL-		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
639-1A	1815																		
	1816	6.99	6.91	7.19	602	37	1233	3301	2759	4139	671	81	3121	8251	4591	10214	3363	2304	4431
	1825																		
	1851																		
640-1A	1815																		
	1816	7.06	6.87	7.96	714	459	986	3126	2809	3639	181	45	407	7903	6996	9049	3699	3013	4520
	1825																		
	1851																		
641-1A	1815																		
	1816	7.00	6.75	7.15	171	61	840	3702	3319	4069	1372	316	1922	6827	6250	7987	4788	3994	6381
	1825																		
	1851																		
642-1A	1815																		
	1816	6.98	6.55	7.23	444	79	1178	4001	3490	4459	553	135	1786	8164	5965	10549	5798	4526	7622
	1825	4.80	4.80	4.80	2090	2090	2090	163	163	163	760	760	760	880	880	880	2942	2942	2942
	1851																		
643-1A	1815																		
	1816	6.96	6.59	7.15	122	76	282	3700	3159	4389	1064	474	1470	6765	4779	9115	4669	3545	6027
	1825																		
	1851																		

RUN SUMMARY - LIQUID ANALYTICAL DATA (CONTINUED)

RUN NO.	ANALYTICAL POINT	TOTAL IONS, PPM			PERCENT SULFATE SATURATION			PERCENT IONIC IMBALANCE		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
639-1A	1815									
	1816	16214	12251	17921	71	3	136	6.2	-2.1	14.3
	1825									
	1851									
640-1A	1815									
	1816	15651	14210	17882	80	46	110	6.8	-4.3	14.9
	1825									
	1851									
641-1A	1815									
	1816	16885	15484	18173	15	5	73	0.6	-6.3	6.4
	1825									
	1851									
642-1A	1815									
	1816	18990	16124	22217	46	6	135	1.3	-10.1	9.0
	1825	7044	7044	7044	70	70	70	2.9	2.9	2.9
	1851									
643-1A	1815									
	1816	16351	14220	19367	11	5	30	3.8	-8.2	12.6
	1825									
	1851									

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ANALYTICAL DATA SUMMARY RUN REPORT
WEDNESDAY THE 21ST OF SEPTEMBER 1977

 RUN SUMMARY     -    LIQUID ANALYTICAL DATA

                                                         CONCENTRATIONS IN LIQUID, PPM

        ANALY       PH              CA++            MG++              SO3=              SO4=               CL-
RUN     TICAL
NO.     POINT AVG   MIN   MAX  AVG  MIN  MAX   AVG   MIN   MAX   AVG   MIN   MAX   AVG    MIN    MAX  AVG   MIN   MAX
------ ----- ---------------  ------------   ---------------  ---------------  -------------------  --------------

VFG-1A 1815
       1816 6.96  6.45  7.07  207   67  764  3333   333  4089   994    22  1945  6524   1368   7899 3982   531  4963
       1825
       1851
VFG-1B 1815
       1816 7.99  7.79  8.21 1265  606 2570   352   163   585    62     0   203  1724   1166   2228 1818   265  4526
       1825
       1851
VFG-1C 1815
       1816 8.00  7.86  8.17 2217 2020 2475   565   493   697   104    45   361  1418    852   1803 4326  3811  5229
       1825 4.76  4.62  4.95 2797 2510 3280   641   578   687   807   542   972  1674   1295   2111 4475  4254  4697
       1851
VFG-1D 1815
       1816 7.96  7.87  8.08 1678 1225 2340   572   463   600    59    13   180   720    238   1460 3923  3545  4431
       1825 5.24  4.87  5.58 1690 1260 2230   575   466   614   248    45   723   762    164   1743 3951  3634  4343
       1851
VFG-1E 1815
       1816 8.02  7.83  8.16 1637 1270 2060   531   400   665    80    22   135   729    352   1326 3537  3102  4343
       1825 4.85  4.29  5.20 1777 1330 2230   561   467   695   695   294  1289   911    369   1507 3552  2836  4343
       1851
VFG-1F 1815
       1816 7.93  7.82  8.00 2188 1850 2800   538   427   634    74     0   226  1140    649   2150 4285  3722  5672
       1825 4.59  4.35  4.79 2506 2090 3540   573   487   691  1106     0  1447  1350    566   1899 4253  3722  5406
       1851
VFG-1G 1815
       1816 7.97  7.73  8.29 2278 2050 2650   638   549   737   130    45   203   624    201   1010 4805  4343  5672
       1825 5.03  4.81  5.45 2412 2050 2669   653   569   780   602   180  1040   878    263   1335 4776  4254  5229
       1851
VFG-1I 1815
       1816 7.99  7.86  8.25 1708 1260 2110   705   635   779    52    22   113   719    475   1204 4248  3811  4786
       1825 4.84  4.53  5.12 1791 1415 2120   718   625   777   530   226   814  1051    614   1607 4137  3634  4875
       1851
VFG-1P 1815
       1816 7.94  7.49  8.14 1560 1350 1940   695   529  1065    68    22   135  1108    723   1622 3730  3013  4077
       1825 4.72  4.50  4.91 1803 1570 2145   704   527  1047   943   316  1379  1518    728   2017 3743  3190  4343
       1851
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RUN SUMMARY - LIQUID ANALYTICAL DATA (CONTINUED)

RUN NO.	ANALYTICAL POINT	TOTAL IONS, PPM			PERCENT SULFATE SATURATION			PERCENT IONIC IMBALANCE		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
VFG-1A	1815									
	1816	15119	2512	18076	21	7	87	4.2	-10.1	13.6
	1825									
	1851									
VFG-1B	1815									
	1816	5268	2501	9580	94	51	128	4.9	-10.2	14.6
	1825									
	1851									
VFG-1C	1815									
	1816	8731	7656	9666	89	56	115	3.6	-7.2	14.3
	1825	10514	9709	11244	110	85	134	7.1	0.3	14.6
	1851									
VFG-1D	1815									
	1816	7086	6007	8777	42	13	94	5.7	-9.7	12.9
	1825	7366	6190	9530	45	10	109	1.9	-10.1	12.5
	1851									
VFG-1E	1815									
	1816	6653	5367	7585	42	21	74	9.7	0.8	15.0
	1825	7635	6250	9121	54	21	88	1.8	-7.7	11.6
	1851									
VFG-1F	1815									
	1816	8401	7348	10223	73	45	126	7.9	-1.5	14.6
	1825	9971	8637	12775	88	40	131	0.9	-6.9	14.9
	1851									
VFG-1G	1815									
	1816	8655	8268	9532	39	13	65	11.6	3.6	15.0
	1825	9504	8809	10425	55	18	89	6.4	-2.7	13.9
	1851									
VFS-1I	1815									
	1816	7609	6588	8955	39	25	71	8.6	2.2	14.7
	1825	8406	7671	9668	57	34	93	1.2	-13.6	10.5
	1851									
VFG-1P	1815									
	1816	7311	6011	8094	57	37	87	6.8	-16.9	14.2
	1825	8862	7517	9547	81	43	109	-5.6	-17.8	11.9
	1851									

RUN SUMMARY - SOLIDS ANALYTICAL DATA

CONCENTRATIONS IN SOLIDS, WT %

RUN NO.	ANALYTICAL POINT	CO2 AVG	CO2 MIN	CO2 MAX	SO2 AVG	SO2 MIN	SO2 MAX	SO3 AVG	SO3 MIN	SO3 MAX	CAO AVG	CAO MIN	CAO MAX	ACID INSOLUBLES AVG	ACID INSOLUBLES MIN	ACID INSOLUBLES MAX	SOLIDS IN SLURRY, WT % AVG	SOLIDS IN SLURRY, WT % MIN	SOLIDS IN SLURRY, WT % MAX
629-1A	1815																		
	1816	0.45	0.11	1.26	23.43	18.00	27.30	8.05	3.40	14.10	26.10	23.00	30.00	3.66	2.56	5.12	8.9	6.9	13.3
630-1A	1815																		
	1816	0.73	0.43	1.10	24.33	19.40	31.10	5.59	3.18	9.16	25.75	22.50	29.30	3.79	3.00	4.47	8.6	7.4	9.7
631-1A	1815																		
	1816	0.63	0.27	1.21	21.34	15.90	26.90	6.27	2.08	9.93	24.04	20.00	29.50	3.97	2.56	5.23	8.4	5.6	9.7
632-1A	1815																		
	1816	0.58	0.37	0.86	22.23	19.60	29.10	5.42	3.23	9.95	23.75	21.70	27.20	3.97	2.80	4.90	8.2	7.5	9.3
633-1A	1815																		
	1816	1.01	0.58	1.33	25.34	21.00	28.90	5.14	3.08	8.01	26.66	23.40	29.30	3.55	2.83	4.80	8.3	7.1	10.2
634-1A	1815																		
	1816	3.83	2.51	6.43	35.56	28.90	40.40	4.17	0.51	11.16	38.16	34.20	43.40	0.93	0.42	1.47	4.3	3.4	6.1
635-1A	1815																		
	1816	3.00	1.70	5.17	35.79	28.20	40.10	10.48	2.21	19.26	42.44	39.50	45.30	0.87	0.02	1.78	8.3	7.2	9.3
636-1A	1815																		
	1816	3.08	1.76	3.68	35.84	32.60	39.45	9.74	3.55	18.78	43.24	39.50	46.96	0.58	0.01	1.29	8.3	7.7	9.1
637-1A	1815																		
	1816	1.67	1.18	2.30	37.90	36.30	39.09	9.21	2.54	15.43	42.66	40.81	44.04	0.15	0.07	0.35	8.3	7.7	9.2
638-1A	1815																		
	1816	1.81	0.44	2.47	35.81	33.29	37.64	9.42	1.49	16.67	39.97	36.33	44.23	0.03	0.01	0.10	4.6	3.6	8.1

RUN SUMMARY - SOLIDS ANALYTICAL DATA (CONTINUED)

RUN NO.	ANALYTICAL POINT	PERCENT SULFITE OXIDATION			STOICHIOMETRIC RATIO			PERCENT IONIC IMBALANCE		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
629-1A	1815									
	1816	21.4	10.3	31.3	1.02	1.00	1.07	-2.3	-7.8	6.3
630-1A	1815									
	1816	15.6	9.0	21.9	1.04	1.02	1.07	-1.4	-8.4	3.9
631-1A	1815									
	1816	19.0	7.5	33.3	1.04	1.01	1.08	0.7	-4.1	7.3
632-1A	1815									
	1816	16.2	8.2	27.2	1.03	1.02	1.05	-0.9	-6.4	4.4
633-1A	1815									
	1816	13.9	7.9	19.6	1.05	1.03	1.06	-1.5	-6.3	4.2
634-1A	1815									
	1816	8.5	1.0	20.7	1.15	1.09	1.26	-2.2	-8.3	7.6
635-1A	1815									
	1816	18.5	4.5	35.3	1.10	1.05	1.21	-0.1	-7.5	7.6
636-1A	1815									
	1816	17.6	6.7	31.2	1.10	1.06	1.12	2.6	-6.3	7.7
637-1A	1815									
	1816	16.0	5.1	24.4	1.05	1.04	1.08	2.1	-6.0	8.0
638-1A	1815									
	1816	16.9	3.1	26.7	1.06	1.02	1.09	-0.7	-8.3	7.9

RUN SUMMARY - SOLIDS ANALYTICAL DATA

CONCENTRATIONS IN SOLIDS, WT %

RUN NO.	ANALYTICAL POINT	CO2 AVG	CO2 MIN	CO2 MAX	SO2 AVG	SO2 MIN	SO2 MAX	SO3 AVG	SO3 MIN	SO3 MAX	CAO AVG	CAO MIN	CAO MAX	ACID INSOLUBLES AVG	ACID INSOLUBLES MIN	ACID INSOLUBLES MAX	SOLIDS IN SLURRY, WT % AVG	SOLIDS IN SLURRY, WT % MIN	SOLIDS IN SLURRY, WT % MAX
639-1A	1815 1816	1.30	0.28	2.10	35.87	26.62	42.29	14.82	5.25	25.92	41.54	33.23	46.88	0.06	0.01	0.30	3.9	0.0	5.5
640-1A	1815 1816	1.33	0.94	1.80	37.22	32.75	38.91	14.93	7.46	23.43	43.54	40.25	46.03	0.33	0.02	1.34	8.3	7.7	9.4
641-1A	1815 1816	1.26	0.62	1.74	40.87	35.65	43.11	7.68	1.42	15.27	42.13	39.55	45.37	0.09	0.03	0.16	8.1	7.5	8.5
642-1A	1815 1816	0.81	0.32	1.28	38.71	35.47	41.98	8.24	0.48	13.78	40.15	36.14	43.53	0.20	0.03	0.85	8.1	6.3	9.0
643-1A	1815 1816	1.15	0.67	1.91	40.64	38.18	42.34	10.70	2.81	13.61	43.79	39.80	45.81	0.14	0.05	0.44	8.1	7.2	8.8

RUN SUMMARY - SOLIDS ANALYTICAL DATA (CONTINUED)

RUN NO.	ANALYTICAL POINT	PERCENT SULFITE OXIDATION AVG	MIN	MAX	STOICHIOMETRIC RATIO AVG	MIN	MAX	PERCENT IONIC IMBALANCE AVG	MIN	MAX
639-1A	1815									
	1816	24.6	9.8	43.8	1.04	1.01	1.06	-4.6	-8.2	1.7
640-1A	1815									
	1816	24.1	13.4	36.4	1.04	1.03	1.05	-2.8	-8.3	2.9
641-1A	1815									
	1816	13.0	2.6	25.5	1.04	1.02	1.05	-1.5	-4.3	3.2
642-1A	1815									
	1816	14.3	1.0	23.7	1.03	1.01	1.04	-1.4	-5.7	5.4
643-1A	1815									
	1816	17.3	5.1	21.3	1.03	1.02	1.06	-1.7	-6.1	2.0

RUN SUMMARY - SOLIDS ANALYTICAL DATA

CONCENTRATIONS IN SOLIDS, WT %

RUN NO.	ANALYTICAL POINT	CO2			SO2			SO3			CAO			ACID INSOLUBLES			SOLIDS IN SLURRY, WT %		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
VFG-1A	1815																		
	1816	0.49	0.19	0.77	25.72	12.84	29.68	2.97	0.02	5.93	26.40	13.03	30.50	2.52	2.23	2.85	8.6	7.6	13.3
VFG-1B	1815																		
	1816	2.43	1.49	4.12	36.67	33.48	38.65	2.90	0.16	7.61	39.27	35.69	42.62	0.16	0.04	0.28	8.4	7.8	9.1
VFG-1C	1815																		
	1816	1.50	0.54	2.47	22.36	18.82	32.55	2.47	0.55	4.01	24.40	20.36	34.83	2.97	2.58	3.36	8.7	8.1	9.8
VFG-1D	1815																		
	1816	2.85	1.37	4.95	22.62	17.73	25.69	1.81	0.03	7.38	26.22	21.75	30.13	2.40	2.24	2.55	8.0	7.3	8.5
VFG-1E	1815																		
	1816	2.20	0.88	4.73	23.01	18.82	26.42	3.52	0.33	9.23	26.03	21.35	29.37	2.86	2.50	3.24	8.4	8.0	8.9
VFG-1F	1815																		
	1816	1.16	0.33	2.25	16.30	12.66	23.91	2.18	0.12	6.52	18.18	15.21	27.51	4.42	3.72	5.97	8.9	7.3	15.0
VFG-1G	1815																		
	1816	3.11	2.03	3.90	21.25	14.04	25.69	1.83	0.26	3.89	24.57	18.13	28.24	3.48	3.20	3.77	8.3	7.2	8.9
VFG-1I	1815																		
	1816	2.10	1.52	2.80	22.97	19.72	26.79	4.42	1.00	8.07	27.24	25.61	28.66	4.77	3.83	5.72	14.6	8.3	15.9
VFG-1P	1815																		
	1816	1.76	1.33	2.58	20.73	18.09	25.44	2.61	0.06	6.05	23.27	19.76	26.97	2.93	2.40	3.30	8.6	7.5	13.4

RUN SUMMARY - SOLIDS ANALYTICAL DATA (CONTINUED)

RUN NO.	ANALYTICAL POINT	PERCENT SULFITE OXIDATION AVG	MIN	MAX	STOICHIOMETRIC RATIO AVG	MIN	MAX	PERCENT IONIC IMBALANCE AVG	MIN	MAX
VFG-1A	1815									
	1816	8.3	0.1	17.4	1.03	1.01	1.09	4.5	-3.5	7.9
VFG-1B	1815									
	1816	5.8	0.4	14.5	1.09	1.05	1.16	5.0	-2.6	8.4
VFG-1C	1815									
	1816	7.9	2.3	12.1	1.09	1.03	1.19	4.9	-2.6	7.7
VFG-1D	1815									
	1816	5.9	0.1	25.0	1.17	1.09	1.28	5.8	1.1	8.4
VFG-1E	1815									
	1816	10.3	1.3	24.3	1.12	1.05	1.30	2.5	-6.1	7.6
VFG-1F	1815									
	1816	9.3	0.6	20.5	1.10	1.02	1.20	4.9	-0.4	8.3
VFG-1G	1815									
	1816	6.3	0.8	13.1	1.21	1.12	1.35	3.0	-2.6	7.4
VFG-1I	1815									
	1816	13.4	2.9	24.5	1.12	1.08	1.16	5.0	1.4	8.2
VFG-1P	1815									
	1816	9.1	0.2	21.0	1.11	1.07	1.17	4.4	-3.3	8.1

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
1	VST	629-1A	SLURRY TO SPRAY TOWER	04/28/76	2330			2320	380	82		7.0
				04/29/76	0730			2400	420	81		7.2
				04/29/76	1530			3760	180	95		13.2
				04/29/76	2330			3880	300	91		13.2
				04/30/76	0730			4000	400	89		13.2
				04/30/76	1530			3500	340	89		11.6
				04/30/76	2330			2800	380	85		8.6
				05/01/76	0730			3640	620	81		11.0
				05/03/76	2330			2960	760	71		7.9
				05/04/76	0730			2440	290	87		7.9
				05/04/76	1530			3040	440	84		9.5
				05/04/76	2330			3640	660	80		10.8
				05/05/76	0730			3830	760	79		11.3
				05/05/76	1530			2480	440	80		7.4

GAS ANALYSES

SCR NO.	SYSTEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
1	VST	629-1A	SLURRY TO SPRAY TOWER	05/05/76	2330			3120	660	77		8.9
				05/06/76	0730			3360	800	74		9.2
				05/06/76	1530			2840	620	77		8.1
				05/06/76	2330			3240	800	73		8.7
				05/07/76	0730			3480	660	79		10.2
				05/07/76	1530							
				05/08/76	0730			3680	680	79		10.9
				05/08/76	1530			3320	700	77		9.4
				05/08/76	2330			3040	700	74		8.4
				05/09/76	0730			3160	800	72		8.4
				05/09/76	1530			2560	540	77		7.3
				05/09/76	2330			3200	580	76		9.1
				05/10/76	0730			3440	740	76		9.7
				05/10/76	1530			2800	640	75		7.8
				05/10/76	2330			3240	900	73		8.7
				05/11/76	0730			3600	1000	69		9.2
				05/11/76	1530			3400	900	71		8.9
				05/11/76	2330			3320	920	69		8.5
				05/12/76	0730			4290	1050	73		11.6
			CLARIFIER UNDERFLOW-V/ST	05/07/76	0730			3480	660	79		10.2
				05/10/76	0730			3440	740	76		9.7
			FILTER CAKE	04/30/76	1530			3590	340	89		11.6
				05/07/76	1530							
				05/10/76	1530			2800	640	75		7.8
		630-1A	SLURRY TO SPRAY TOWER	05/12/76	1530			3820	50	99		14.0
				05/12/76	2330			3880	80	99		14.1
				05/13/76	0730			2440	300	86		7.8
				05/13/76	1530			2120	180	91		7.1
				05/13/76	2330			2880	220	92		9.8
				05/14/76	0730			2960	340	87		9.6
				05/14/76	1530			2800	160	94		9.7
				05/14/76	2330			2840	110	96		10.2
				05/15/76	0730			3200	360	88		10.4
				05/15/76	1530			3800	440	87		12.3
				05/15/76	2330			2720	260	89		9.0
				05/16/76	0730			3000	400	85		9.5
				05/16/76	1530			2920	200	92		10.0
				05/16/76	2330			3080	260	91		10.4
				05/17/76	0730			3360	200	93		11.6
				05/17/76	1530			3240	100	97		11.6
				05/17/76	2330			3320	90	97		11.9
				05/18/76	0730			3400	200	93		11.9
			CLARIFIER UNDERFLOW-V/ST	05/14/76	0730			2960	340	87		9.6
				05/17/76	0730			3360	200	93		11.6
			FILTER CAKE	05/14/76	1530			2800	160	94		9.7

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
1	VST	630-1A	FILTER CAKE	05/17/76	1530			3240	100	97		11.6
		631-1A	SLURRY TO SPRAY TOWER	05/18/76	1530			2960	1020	62		10.4
				05/18/76	2330			3000	1000	63		10.8
				05/19/76	0730			3360	1040	66		12.5
				05/19/76	1530			2800	720	71		11.4
				05/19/76	2330			2640	840	65		9.7
				05/20/76	0730			3800	1500	56		12.2
				05/20/76	1600			3920	1600	55		12.2
				05/20/76	2330			3520	420	87		17.4
				05/21/76	0730			3000	200	93		15.9
				05/21/76	1530			2640	520	78		11.8
				05/21/76	2330			2520	420	81		11.7
				05/22/76	0730			2520	680	70		10.1
				05/22/76	1530			2480	640	71		10.1
				05/22/76	2330			2600	930	65		9.8
				05/23/76	0730			2680	800	67		10.2
				05/23/76	1530			3280	520	82		15.4
				05/23/76	2330			2600	420	82		12.2
				05/24/76	0730			2240	420	79		10.1
			FILTER CAKE	05/21/76	1530			2640	520	78		11.8
				05/24/76	0730			2240	420	77		10.1
		632-1A	SLURRY TO SPRAY TOWER	05/28/76	2330			2800	760	73		9.4
				05/29/76	0730			3360	690	78		12.6
				05/29/76	1530			3080	460	83		12.4
				05/29/76	2330			3120	380	86		13.0
				05/30/76	0730			3000	300	89		12.9
				05/30/76	1530			2600	320	86		10.8
				05/30/76	2330			2200	220	89		9.4
				05/31/76	0730			2040	220	88		8.7
				05/31/76	1530			2600	440	81		10.2
				05/31/76	2330			2520	600	74		8.9
				06/01/76	0730			2750	760	69		9.2
				06/01/76	1530			3160	1020	64		9.8
				06/01/76	2330			2800	400	84		11.4
				06/02/76	0730			2760	520	79		10.5
				06/02/76	1530			2960	400	85		12.1
				06/02/76	2330			2800	700	72		9.7
				06/03/76	0730			2920	340	87		12.3
				06/03/76	2300			2320	140	93		10.4
			CLARIFIER UNDERFLOW-V/ST	05/28/76	2330			2800	760	70		9.4
				05/29/76	2330			3120	380	86		13.0
				05/30/76	2330			2200	220	89		9.4
			FILTER CAKE	05/29/76	0730			3360	690	78		12.6
				05/30/76	0730			3000	300	87		12.9
				05/31/76	0730			2040	220	88		8.7

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
1	VST	633-1A	SLURRY TO SPRAY TOWER	06/05/76	1530			2920	460	83		8.3
				06/05/76	2330			2640	120	95		8.6
				06/06/76	0730			3080	160	94		10.0
				06/06/76	1530			2840	70	97		9.5
				06/06/76	2330			2800	60	99		9.4
				06/07/76	0730			3160	140	95		10.3
				06/07/76	1530			2960	80	97		9.9
				06/07/76	2330			3160	230	91		9.9
				06/08/76	0730			3600	420	87		10.9
				06/08/76	1530			2840	240	91		8.9
				06/08/76	2330			3100	240	91		9.8
				06/09/76	0730			3000	240	91		9.4
				06/09/76	1530			2960	240	91		9.3
				06/09/76	2330			3040	360	87		9.1
				06/10/76	0730			3400	560	82		9.6
				06/10/76	1530			2800	100	96		9.3
				06/10/76	2330			2200	180	91		6.9
				06/11/76	0730			2480	380	83		7.1
				06/11/76	1530			3360	440	85		9.9
				06/11/76	2330			3400	280	91		10.6
				06/12/76	0730			3080	100	96		10.2
				06/12/76	1530			3040	80	97		10.2
				06/12/76	2330			2600	140	94		8.4
				06/13/76	0730			2720	140	94		8.8
				06/13/76	1530			3000	100	96		9.9
				06/13/76	2330			3320	120	96		11.0
				06/14/76	0530			3320	220	93		10.6
			CLARIFIER UNDERFLOW-V/ST	06/07/76	0730			3160	140	95		10.3
			FILTER CAKE	06/07/76	1530			2960	80	97		9.9
				06/11/76	1530			3360	440	85		9.9
		634-1A	SLURRY TO SPRAY TOWER	06/20/76	0730			1800	340	79		5.3
				06/20/76	1530			2060	470	75		5.7
					1530			2060	470	75		5.7
				06/20/76	2330			1480	220	83		4.6
					2330			1480	220	83		4.6
				06/21/76	0730			1560	260	81		4.7
				06/21/76	1530			1800	360	78		5.2
				06/21/76	2330			2120	540	72		5.6
				06/22/76	0730			1980	350	80		5.9
				06/22/76	1530			1840	260	84		5.8
					1530			1840	260	84		5.8
				06/22/76	2330			1880	280	85		5.8
					2330			1880	280	85		5.8
				06/23/76	0730			1960	260	85		5.2
				06/23/76	1530			2640	660	72		7.1

GAS ANALYSES

SCR NO.	SYSTEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
1	VST	634-1A	SLURRY TO SPRAY TOWER	06/23/76	1530			2640	660	72		7.1
				06/23/76	2330			2600	700	70		6.8
					2330			2600	700	70		6.8
				06/24/76	0730			2760	780	69		7.0
					0730			2760	780	69		7.0
				06/24/76	1530			3520	1000	68		8.9
					1530			3520	1000	68		8.9
				06/24/76	2330			3340	860	69		7.7
					2330			3040	860	69		7.7
				06/25/76	0730			2080	320	83		6.4
					0730			2080	320	83		6.4
				06/25/76	1530			2280	420	80		6.7
				06/25/76	2330			2040	300	84		6.3
				06/26/76	0730			3200	820	72		8.5
				06/26/76	1530			3000	900	70		7.8
				06/26/76	2330			2600	640	73		7.0
				06/27/76	0730			3240	920	68		8.2
				06/27/76	1530			2520	540	76		7.1
				06/27/76	2330			2720	520	75		7.5
				06/28/76	0730			2960	760	71		7.9
				06/28/76	1530			3200	900	72		8.0
				06/28/76	2330			2760	580	77		7.9
				06/29/76	0730			3120	700	75		8.7
				06/29/76	1530			2580	640	75		8.0
				06/29/76	2330			3080	700	75		9.5
				06/30/76	0730			3760	1020	70		9.7
				06/30/76	1530			3480	960	69		9.0
				06/30/76	2330			2320	440	79		6.8
				07/01/76	0730			2120	320	83		5.5
					0730			2120	320	83		5.5
				07/01/76	1530			2200	400	80		6.5
				07/01/76	2330			2360	440	79		6.9
				07/02/76	0730			2800	640	75		7.9
					0730			2800	640	75		7.6
				07/02/76	1530			2400	480	79		6.9
			CLARIFIER UNDERFLOW-V/ST	25/76/06	0730			2080	320	83		6.4
				06/22/76	2330			1880	280	83		5.8
				06/25/76	0730			2080	320	83		6.4
				06/28/76	0730			2960	760	71		7.9
				07/02/76	0730			2800	640	75		7.8
			FILTRATE	04/23/75	0700							
			FILTER CAKE	06/23/76	0730			1960	260	85		6.2
				06/2[illegible]/76	1530			3200	800	72		8.6
				07/02/76	1530			2400	480	73		6.9
		635-1A	SLURRY TO SPRAY TOWER	07/16/76	2330			2720	340	86		8.7

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GAS ANALYSES

                                                                        BOIL                                MAKE
                                                                 GAS/   LOAD    SO2    SO2   SO2      O2    PER
SCR  SYS-  RUN                                                   TIME   MEGA     IN    OUT   REM      IN    PASS
NO.  TEM   NO.    SAMPLE NAME                  DATE      TIME    FLAG   WATT    PPM    PPM    %       %    MMOL/L
---  ----  ------ ------------------------- --------     ----    ----   ----   ----   ----   ---    ----   ------
  1  VST   635-1A SLURRY TO SPRAY TOWER      07/17/76    0730                  2920    480    82              8.9
                                             07/17/76    1530                  3080    700    75              8.5
                                             07/17/76    2330                  2960    640    76              8.3
                                             07/18/76    0730                  2520    400    82              7.7
                                             07/20/76    0730                  2080    200    89              6.9
                                             07/20/76    1530                  1960    200    89              6.4
                                             07/20/76    2330                  2000    260    86              6.3
                                             07/21/76    0730                  1700    130    92              5.8
                                             07/21/76    1530                  2160    320    84              6.7
                                             07/21/76    2330                  3600   1300    60              8.0
                                             07/22/76    0730                  2920    720    73              7.9
                                             07/22/76    1530                  3520   1260    60              7.9
                                             07/22/76    2330                  3200    960    67              7.9
                                             07/23/76    0730                  2720    550    78              7.8
                                             07/23/76    1530                  2560    400    83              7.9
                                             07/23/76    2330                  2760    600    76              7.8
                                             07/24/76    0730                  2920    600    77              8.4
                                             07/24/76    1530                  2120    320    83              6.5
                                             07/24/76    2330                  2280    340    83              7.1
                                             07/25/76    0730                  2280    300    85              7.2
                                             07/25/76    1530                  2080    300    84              6.5
                                             07/25/76    2330                  2600    450    83              8.6
                                                         2330                  2630    400    83              8.0
                                             07/26/76    0730                  2800    590    77              8.0
                            FILTER CAKE      07/17/76    1530                  3080    700    75              8.5
                                             07/20/76    1530                  1960    200    89              6.4
                                             07/21/76    1530                  2160    320    84              6.7
                                             07/22/76    1530                  3520   1260    60              7.9
                                             07/23/76    1530                  2560    400    83              7.9
                                             07/24/76    1530                  2120    320    83              6.5
                                             07/25/76    1530                  2080    300    84              6.5
           636-1A SLURRY TO SPRAY TOWER      07/26/76    1530                  3400    420    86              7.8
                                             07/28/76    2330                  3300    580    80              7.0
                                             07/29/76    0730                  3560    740    77              7.3
                                             07/29/76    1930                  3000    480    82              6.5
                                             07/29/76    2330                  2920    390    85              6.6
                                             07/30/76    0730                  3080    420    85              6.9
                                             07/30/76    1530                  2920    420    84              6.5
                                             07/30/76    2330                  3000    420    84              6.7
                                             07/31/76    0730                  3000    360    88              6.9
                                             07/31/76    1530            148   3040    420    85              6.8
                                                         1530            148   3040    420    85              6.8
                                             07/31/76    2330                  2960    400    84              6.4
                                             08/01/76    0730                  2680    320    88              6.7
                                             08/01/76    1530                  2920    360    86              6.7
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GAS ANALYSES

                                                                               BOIL
                                                                        GAS/   LOAD    SO2    SO2   SO2            MAKE
SCR  SYS-  RUN                                                          TIME   MEGA    IN     OUT   REM     O2     PER
NO.  TEM   NO.    SAMPLE NAME                   DATE       TIME         FLAG   WATT    PPM    PPM   %       IN     PASS
---  ----  ------ ------------------------   --------   ----         ----   ----    ----   ----  ---     %      MMOL/L
                                                                                                          ----   ------
  1  VST   636-1A SLURRY TO SPRAY TOWER      08/01/76   2330                   148    2760    300   88                 6.4
                                                        2330                   148    2760    300   88                 6.4
                                             08/02/76   0730                   128    2800    280   89                 6.6
                                             08/02/76   1530                   128    2680    340   86     9.0         6.1
                                                        1530                   128    2680    340   86     9.0         6.1
                                             08/02/76   2330                   113    2760    370   85     9.8         6.2
                                             08/03/76   0730                   144    2800    380   85     9.5         6.3
                                             08/03/76   1530                   143    2320    220   89     9.0         5.5
                                             08/03/76   2330                   143    3120    540   81     8.8         6.7
                                             08/04/76   0730                   149    2920    460   85     7.8         6.4
                                             08/04/76   1130                   148    3000    460   83     8.0         6.6
                  FILTER CAKE                07/26/76   1530                          3400    420   86                 7.8
                                             07/29/76   1930                          3000    480   82                 6.5
                                             07/30/76   1530                          2920    420   84                 6.5
                                             07/31/76   1530                   148    3040    420   85                 6.8
                                             08/01/76   1530                          2920    360   86                 6.7
                                             08/02/76   1530                   128    2680    340   86     9.0         6.1
                                             08/03/76   1530                   143    2320    220   89     9.0         5.5
                                             08/04/76   1130                   148    3000    460   83     8.0         6.6
           637-1A SLURRY TO SPRAY TOWER      08/06/76   1930                   143    3040    800   71     7.5         8.0
                                             08/06/76   2330                   143    3000    920   70     7.4         7.8
                                             08/07/76   0730                   128    3080    860   69     7.9         7.9
                                             08/07/76   1530                   140    2900    660   75     7.3         8.0
                                             08/07/76   2330                          2760    660   73     7.5         7.5
                                             08/08/76   0730                   145    2680    540   78     7.9         7.7
                                             08/08/76   1530                   143    2680    620   74     6.5         7.4
                                             08/08/76   2330                   145    3000    780   71     6.6         7.9
                                             08/09/76   0730                   144    2920    700   73     6.8         8.0
                                             08/09/76   1530                   143    3120    980   69     6.0         8.0
                                             08/09/76   2330                   144    3280   1000   56     6.5         8.1
                                             08/10/76   0730                   145    3520   1040   67     8.2         8.8
                                                        0730                   145    3520   1040   67     8.2         8.8
                                             08/10/76   1530                   144    2800    740   71     8.0         7.3
                                             08/10/76   2330                   148    2800    700   72     8.5         7.5
                                             08/11/76   0730                   148    2920    700   73     9.0         8.0
                                             08/11/76   1530                   148    3040    900   67     8.2         7.6
                                             08/11/76   2330                   144    3120    920   67     8.0         7.8
                                             08/12/76   0730                   148    3320    940   69                 8.4
                  FILTER CAKE                08/06/76   1930                   143    3040    800   71     7.5         8.0
                                             08/07/76   1530                   140    2900    660   75     7.3         8.0
                                             08/08/76   1530                   148    2680    620   74     6.5         7.4
                                             08/09/76   1530                   143    3120    880   69     6.0         8.0
                                             08/10/76   1530                   144    2800    740   71     8.0         7.3
                                             08/11/76   1530                   148    3040    900   67     8.2         7.6
           638-1A SLURRY TO SPRAY TOWER      08/16/76   1930    X              146    2680    640   76                 7.3
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GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
1	VST	638-1A	SLURRY TO SPRAY TOWER	08/16/76	2330	X	141	2760	660	73	8.5	7.5
				08/17/76	0730	X	143	2630	520	78	7.3	7.8
				08/17/76	1530		150	2000	280	84	7.4	6.3
				08/17/76	2330		110	2520	480	79	8.0	7.4
				08/18/76	0730		142	2800	610	76	10.5	7.9
					0730		142	2800	610	76	10.5	7.9
				08/18/76	1530		143	2120	360	81	8.6	6.4
				08/18/76	2330		146	2240	320	84	9.0	7.0
					2330		146	2240	320	84	9.0	7.0
				08/19/76	0530		141	2240	320	84		7.0
				08/19/76	1600		148	2400	460	79	9.1	7.0
				08/19/76	2330		136	2760	620	75	8.5	7.7
				08/20/76	0730		138	3100	760	73	8.8	8.4
				08/20/76	1530		143	2840	660	74	7.9	7.8
				08/20/76	2330		148	2800	660	74	7.2	7.7
				08/21/76	0730		143	2960	650	76	8.5	8.3
				08/21/76	1530		146	2720	660	73	8.0	7.4
				08/21/76	2330		145	2640	600	75	7.2	7.3
				08/22/76	0730		135	2760	600	76	7.9	7.8
				08/22/76	1530		147	2720	590	75		7.7
				08/22/76	2330		146	2680	540	78		7.7
				08/23/76	0730		148	2440	340	85		7.7
				08/23/76	1530		145	2120	220	88	6.3	7.0
				08/23/76	2330		142	2800	520	79	6.7	8.2
					2330		142	2800	520	79	6.7	8.2
				08/24/76	0530		100	2720	500	80	6.5	8.0
			FILTER CAKE	08/16/76	1930	X	146	2680	640	73		7.3
				08/17/76	1530		150	2000	280	84	7.4	6.3
				08/18/76	1530		143	2120	360	91	8.6	6.4
				08/19/76	1600		148	2400	460	79	9.1	7.0
					1600		148	2400	460	79	9.1	7.0
					1600		148	2400	460	79	9.1	7.0
				08/20/76	1530		143	2840	660	74	7.9	7.8
				08/21/76	1530		146	2720	660	73	8.0	7.4
				08/22/76	1530		147	2720	580	76		7.7
				08/23/76	1530		145	2120	220	88	6.3	7.0
		639-1A	SLURRY TO SPRAY TOWER	08/24/76	1530	X	145	2560	540	77	6.8	7.3
				08/24/76	2330	Y	103	2560	0	100	6.4	9.5
				08/25/76	0730	X	105	2640	30	99	6.5	9.7
				08/25/76	1530	X	145	2800	20	99	8.0	10.3
					1530	X	145	2800	20	99	8.0	10.3
				08/26/76	0730	X	145	2640	30	99	7.8	9.7
				08/26/76	1530	X	144	2600	55	98	8.5	9.4
					1530	X	144	2600	55	98	8.5	9.4
					1530	Y	144	2600	55	98	8.5	9.4

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
1	VST	639-1A	SLURRY TO SPRAY TOWER	08/26/76	2330	X	142	2880	180	93	8.0	9.9
				08/27/76	0730		140	3000	500	81	8.2	9.1
				08/27/76	1530		145	2960	560	79	9.7	8.7
				08/27/76	2330		144	3160	680	76	8.5	8.9
					2330		144	3160	680	76	8.5	8.9
				08/28/76	0730		140	2600	380	84	8.4	8.1
				08/28/76	1530		145	2680	460	81	8.5	8.0
				08/28/76	2330		145	3040	560	80	8.8	9.0
				08/29/76	0730		145	2160	200	90	8.5	7.2
				08/29/76	1530		144	2080	200	89	9.2	6.9
				08/29/76	2330		142	2280	300	85	9.2	7.2
				08/30/76	0730		117	2600	320	85	9.1	8.3
				08/30/76	1530		146	2080	200	89	8.5	6.9
				08/30/76	2330		135.	2280	300	85	8.4	7.2
				08/31/76	1530		144	2920	660	75	9.2	8.1
				08/31/76	2330		148	3200	800	72	8.8	8.6
				09/01/76	0530		141	3120	740	74	9.0	8.5
			FILTER CAKE	08/24/76	1530	X	145	2560	540	77	6.8	7.3
				08/25/76	1530	X	145	2800	20	99	8.0	10.3
					1530	X	145	2800	20	99	8.0	10.3
					1530	X	145	2800	20	99	8.0	10.3
				08/26/76	1530	X	144	2600	55	98	8.5	9.4
					1530	X	144	2600	55	98	8.5	9.4
					1530	X	144	2600	55	98	8.5	9.4
				08/27/76	1530		145	2960	560	79	8.7	8.7
				08/28/76	1530		145	2680	460	81	8.5	8.0
				08/29/76	1530		144	2080	200	89	9.2	6.9
				08/30/76	1530		146	2080	200	89	8.5	6.9
				08/31/76	1530		144	2920	660	75	9.2	8.1
		640-1A	SLURRY TO SPRAY TOWER	09/02/76	1830		145	2680	460	81	9.0	8.0
				09/02/76	2330		111	2560	360	84	8.6	8.0
				09/03/76	0730		115	2560	380	84	10.2	7.9
				09/03/76	1530		144	3160	660	77	10.0	9.0
				09/03/76	2330		142	3360	900	74	9.6	9.2
				09/04/76	0730		144	3120	720	74	7.5	8.6
				09/04/76	1530		144	2960	650	76	7.0	8.4
				09/04/76	2330		141	3280	740	75	7.2	9.1
				09/05/76	0730		145	3240	620	79	7.8	9.5
					0730		145	3240	620	79	7.8	9.5
				09/05/76	1530		144	2960	600	77	7.2	8.5
				09/05/76	2330		143	3000	540	80	7.4	8.9
				09/06/76	0730		119	2600	320	86	7.5	8.3
				09/06/76	1530		143	2540	400	83	7.3	8.1
				09/06/76	2330		145	2920	500	81	7.6	8.8
				09/07/76	0730		144	3600	580	82		11.0

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
1	VST	640-1A	SLURRY TO SPRAY TOWER	09/07/76	1530		148	3120	620	79	7.2	9.0
				09/07/76	2330		137	3240	680	77	7.5	9.2
				09/08/76	0730		148	2960	580	78	7.0	8.6
				09/08/76	1530		113	2840	550	78	7.0	8.3
				09/08/76	2330		105	2760	480	81	5.5	5.3
				09/09/76	0430		109	2840	540	79		8.3
			FILTER CAKE	09/03/76	1530		144	3160	660	77	10.0	9.0
				09/04/76	1530		144	2980	650	76	7.0	8.4
				09/05/76	1530		144	2960	600	77	7.2	8.5
				09/06/76	1530		145	2640	400	83	7.5	8.1
				09/08/76	1530		113	2840	550	78	7.0	8.3
		641-1A	SLURRY TO SPRAY TOWER	09/09/76	1600	X	108	2840	800	69	6.0	9.4
				09/09/76	2330	X	100	2200	460	77		8.1
				09/10/76	0730	X	100	2200	460	77	9.0	9.1
				09/10/76	1530	X	150	2440	660	70		8.2
				09/10/76	2330	X	137	2560	540	77		9.4
				09/11/76	0730	X	146	2760	460	81		10.8
				09/11/76	1530		148	2720	240	90	10.2	11.8
				09/11/76	2330		117	2600	110	95	10.0	11.9
				09/12/76	0730		140	3000	160	94	10.0	13.6
				09/12/76	1530		148	2680	140	94	9.9	12.2
				09/12/76	2330		141	2520	80	96	9.8	11.7
				09/13/76	0730		146	2760	80	97	10.2	12.9
				09/13/76	1530		163	2600	100	96	9.9	12.0
				09/13/76	2330		146	2720	100	96	9.5	12.6
				09/14/76	0730		146	2960	110	96	9.5	13.7
				09/14/76	1530		142	2800	200	92	9.7	12.4
			FILTER CAKE	09/09/76	1600	X	108	2840	800	69	6.0	9.4
				09/10/76	1530	X	150	2440	660	70		8.2
				09/11/76	1530		148	2720	240	90	10.2	11.8
				09/12/76	1530		148	2680	140	94	9.9	12.2
				09/13/76	1530		163	2600	100	96	9.9	12.0
				09/14/76	1530		142	2800	200	92	9.7	12.4
		642-1A	SLURRY TO SPRAY TOWER	09/15/76	1600		143	2520	520	77	9.5	12.1
				09/15/76	2330		143	2520	560	62		9.8
				09/16/76	0730		144	2390	690	68	9.5	10.1
				09/16/76	1530		145	2400	620	71	9.5	10.7
				09/16/76	2330		143	2600	700	70	12.5	11.4
				09/17/76	0730		147	2840	850	67		11.9
				09/17/76	1530		147	2640	700	71	7.5	11.6
				09/17/76	2330		147	2600	580	71	6.5	11.5
				09/18/76	0730		144	2760	560	77	7.8	13.3
				09/18/76	1530		145	2320	520	75	8.0	10.9
				09/18/76	2330	X	147	2400	680	69	7.5	10.3
				09/19/76	0730	X	147	2860	220	91	7.5	16.3

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
1	VST	642-1A	SLURRY TO SPRAY TOWER	09/19/76	1530	X	148	2800	400	84	8.0	14.7
				09/19/76	2330	X	145	2240	120	94	7.2	13.1
				09/20/76	0730	X		2200	120	94	7.2	12.9
				09/20/76	1530	X	146	2200	620	59	5.0	9.4
				09/20/76	2330	X	115	2440	780	65	4.2	9.8
				09/21/76	0500	X	149	2720	785	68	5.5	11.5
				09/22/76	1530		147	2640	800	66	6.8	10.9
				09/22/76	2330		131	2680	870	64	8.8	10.7
				09/23/76	0730		149	2440	780	65	8.3	9.8
				09/23/76	1530		149	2560	820	64	8.3	10.3
				09/23/76	2330		124	3240	1020	65	9.5	13.1
				09/24/76	0730		127	2960	980	63		11.7
				09/24/76	1530		144	2920	960	64	8.5	11.6
				09/24/76	2330		143	2640	980	63	9.0	10.4
				09/25/76	0730		143	2560	780	66	8.8	10.6
				09/25/76	1530		148	2440	600	73	9.2	11.1
				09/25/76	2330		139	2560	780	66	8.5	10.6
				09/26/76	0730		137	2800	940	63	8.0	11.0
				09/26/76	1530		146	2560	840	64	8.2	10.1
				09/26/76	2330		145	2720	960	61	7.8	10.3
				09/27/76	0500		137	2560	900	61		9.7
			FILTER CAKE	09/15/76	1600		143	2520	520	77	9.5	12.1
				09/16/76	1530		145	2400	620	71	9.5	10.7
				09/17/76	1530		147	2640	700	71	7.5	11.6
				09/18/76	1530		145	2320	520	75	8.0	10.9
				09/19/76	1530	X	148	2800	400	84	8.0	14.7
				09/20/76	1530	X	146	2200	620	69	5.0	9.4
				09/22/76	1530		147	2640	800	66	6.8	10.9
				09/23/76	1530		149	2560	820	64	8.3	10.3
				09/24/76	1530		144	2920	960	64	8.5	11.6
				09/25/76	1530		148	2440	600	73	9.2	11.1
				09/26/76	1530		146	2560	840	64	8.2	10.1
			SLURRY FROM SPRAY TOWER	04/01/75	0700							
		643-1A	SLURRY TO SPRAY TOWER	09/27/76	1530	X	143	2880	320	89	6.5	9.4
				09/27/76	2330	X	145	2720	230	91	6.2	9.1
				09/28/76	0730		110	2680	30	99	9.7	9.8
				09/28/76	1530		148	2640	60	97		9.5
				09/28/76	2330		134	2680	60	98	9.5	9.7
				09/29/76	0730		146	2800	40	98	8.0	10.2
				09/29/76	1530		145	2520	40	98	8.2	9.2
				09/29/76	2330		136	2440	40	98	8.0	8.9
				09/30/76	0730		145	2520	40	98	8.6	9.2
				09/30/76	2330		135	2440	40	98		8.9
				10/01/76	0730		145	2680	40	98	9.0	9.8
				10/01/76	1530		147	2560	40	98	10.0	9.7

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          GAS ANALYSES


                                                                       BOIL                            MAKE
                                                                 GAS/  LOAD    SO2   SO2  SO2    O2    PER
SCR  SYS-  RUN                                                   TIME  MEGA    IN    OUT  REM    IN    PASS
NO.  TEM   NO.     SAMPLE NAME                 DATE      TIME    FLAG  WATT    PPM   PPM   X      X   MMOL/L
---  ----  ------  ------------------------  --------  ----    ----  ----    ----  ----  ---   ----  ------
  1  VST   647-1A  SLURRY TO SPRAY TOWER     10/01/76  2330           141    2520    40   98    9.9     9.2
                                             10/02/76  0730           146    2720    40   98    9.5     9.9
                                             10/02/76  1530           145    2520    20   99    9.0     9.3
                                             10/02/76  2330           140    2440    50   98            8.8
                                             10/03/76  0730           141    2520   100   96    8.3     8.9
                                             10/03/76  1530           140    2000    30   99    8.3     7.3
                                             10/03/76  2330           110    2060    60   97    8.2     7.2
                                             10/04/76  0730           142    2720    30   99    8.5    10.0
                                             10/04/76  1530           144    2130    30   99    8.9     7.7
                                             10/04/76  2330           144    2680    60   98    9.6     9.7
                                             10/05/76  0730           144    2920    50   98    9.5    10.6
                   FILTER CAKE               10/01/76  1530           147    2660    40   98   10.0     9.7
                                             10/02/76  1530           145    2520    20   99    8.0     9.3
                                             10/03/76  1530           140    2000    30   98    8.3     7.3
                                             10/04/76  1530           144    2100    30   98    9.9     7.7
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GAS ANALYSES

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                                                                             BOIL                                 MAKE
                                                                      GAS/   LOAD    SO2    SO2   SO2      O2     PER
SCR  SYS-  RUN                                                        TIME   MEGA    IN     OUT   REM      IN     PASS
NO.  TEM   NO.     SAMPLE NAME                DATE        TIME        FLAG   WATT    PPM    PPM   %        %      MMOL/L
---  ----  ------  -------------------------  --------    ----        ----   ----    ----   ----  ---      ----   ------
  1  VST   VFG-1A  SLURRY TO SPRAY TOWER      10/10/76    1730         Z      142    3000   900   67                 7.4
                                              10/10/76    2330                115    2760    80   97       8.5       9.9
                                              10/11/76    0730                100    3000   380   86       5.4       9.6
                                              10/11/76    1530                107    2560   440   81       4.5       7.7
                                              10/11/76    2330                107    2760   460   81       3.9       8.3
                                              10/12/76    0730                142    3140   280   91       6.5      10.5
                                              10/12/76    1530                146    2720   400   84       5.8       8.4
                                              10/12/76    2330                143    3000   200   93       6.5      10.3
                                              10/13/76    0730                145    2840    60   98       3.6      10.3
                                              10/13/76    1530                146    3000    40   99       6.2      11.0
                                              10/13/76    2330                146    3000    60   98       5.2      10.9
                                              10/14/76    0730                148    3120    40   99       5.2      11.4
                                              10/14/76    1530                146    3080    40   99       5.6      11.3
                                              10/14/76    2330                143    2960    80   97       5.1      10.7
                                              10/15/76    0730                146    3100   240   91       4.8      10.5
                                              10/15/76    1530                150    2840   280   89       5.5       9.4
                                              10/15/76    2330                147    2960   320   88       5.0       9.7
                                              10/16/76    0730                145    3260   120   96       5.1      11.6
                                              10/16/76    1530                149    3240    70   98       5.1      11.7
                                              10/16/76    2330                141    3360    60   98       6.0      12.2
                                              10/17/76    0730                148    3560    50   98       5.5      13.0
                                              10/17/76    1530                149    3320    50   98       6.0      12.1
                                              10/17/76    2330                150    3440    60   98       7.5      12.5
                   FILTER CAKE                10/11/76    1530                107    2560   440   81       4.5       7.7
                                              10/12/76    1530                146    2720   400   84       5.8       8.4
                                              10/13/76    1530                146    3000    40   99       6.2      11.0
                                              10/14/76    1530                146    3080    40   99       5.6      11.3
                                              10/15/76    1530                150    2840   280   89       5.5       9.4
                                                          1530                150    2840   280   89       5.5       9.4
                                              10/16/76    1530                149    3240    70   98       5.1      11.7
                                              10/17/76    1530                149    3320    50   98       6.0      12.1
           VFG-1B  SLURRY TO SPRAY TOWER      10/21/76    0730         Z      136    3280   860   71       8.8       8.5
                                              10/21/76    1530         Z      137    2600   560   76      12.6       7.3
                                              10/21/76    2330         Z      147    2660   610   75       9.5       7.4
                                              10/22/76    0730         Z      148    2800   600   76       9.3       7.9
                                              10/22/76    1530         Z      146    2920   660   75      10.2       8.1
                                              10/22/76    2330         Z      145    2990   650   75       7.8       8.3
                                              10/23/76    0730         Z      114    2680   580   76       8.9       7.6
                                                          0730         Z      114    2680   580   76       8.9       7.6
                                              10/23/76    1530         Z      144    2800   660   74       9.5       7.7
                                              10/23/76    2330         Z      149    2640   590   75       9.0       7.4
                                              10/24/76    0730         Z      149    2600   620   74       9.2       7.1
                                              10/24/76    1530         Z      149    2520   540   76       7.5       7.1
                                              10/24/76    2330         Z      149    2740   650   74       7.0       7.5
                                              10/25/76    0730         Z      146    3200   920   72      11.4       8.5
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GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
1	VST	VFG-1P	SLURRY TO SPRAY TOWER	10/25/76	1530	Z	145	2800	660	74	8.5	7.7
				10/25/76	2330	Z	149	2800	650	74	7.8	7.7
				10/26/76	0730	Z	148	3320	870	71	7.8	8.7
				10/25/76	1530	Z		3120	790	72	9.4	8.3
					1530	Z		3120	790	72	9.4	8.3
				10/26/76	2330			3040	740	73	7.6	8.2
				10/27/76	0730		149	3200	780	73	8.4	8.7
				10/27/76	1530		148	2920	700	73	7.4	8.0
				10/27/76	2330		125	3480	1000	68	9.0	8.3
				10/28/76	0730		121	3520	940	70	10.2	9.2
				10/28/76	1530		138	3320	900	70	9.8	8.6
				10/28/76	2330		150	2960	680	74	8.8	8.2
				10/29/76	0730			2880	620	76	7.9	8.1
			FILTER CAKE	10/22/76	1530	Z	146	2920	560	75	10.2	8.1
				10/23/76	1530	Z	144	2800	660	74	9.5	7.7
				10/24/76	1530	Z	149	2520	540	76	7.5	7.1
				10/25/76	1530	Z	145	2800	660	74	8.5	7.7
		VFG-1C	SLURRY TO SPRAY TOWER	10/29/76	1530		150	3160	700	75	4.5	8.8
				10/29/76	2330		150	2920	780	70	5.8	7.6
				10/30/76	0730		150	2920	780	70	4.8	7.6
				10/30/76	1530		139	2840	760	73	5.0	7.4
				10/30/76	2330		150	2600	520	78	4.4	7.5
				10/31/76	2330			2680	600	75	5.4	7.5
				11/01/76	0730		153	3360	1000	67	6.0	8.3
				11/01/76	1530		149	2520	560	75	11.5	7.0
				11/01/76	2330		150	3040	820	73	8.2	7.9
				11/02/76	0730		156	3080	780	72	5.2	8.2
				11/02/76	1530		149	2960	820	69	5.5	7.6
			SLURRY FROM SPRAY TOWER	11/01/76	1530		149	2520	560	75	11.5	7.0
				11/01/76	2330		150	3040	820	70	8.2	7.9
				11/02/76	0730		156	3080	780	72	5.2	8.2
				11/02/76	1530		149	2960	820	69	5.5	7.6
		VFG-1D	SLURRY TO SPRAY TOWER	11/02/76	2330		132	3480	460	85	5.5	6.3
				11/03/76	0730		94	3080	940	66	5.6	4.3
				11/03/76	1530		137	2880	270	93	5.7	5.5
				11/03/76	2330		126	3040	300	89	6.2	5.7
				11/04/76	0730		142	3080	300	89	6.5	5.6
				11/04/76	1530		141	3600	400	88	5.5	6.7
				11/04/76	2330		148	3440	300	90	5.0	6.6
				11/05/76	0730		150	3680	260	92	5.2	7.2
				11/05/76	1530		143	2920	160	94	6.7	5.8
				11/05/76	2330		156	3120	160	94	4.0	6.2
				11/06/76	0730		149	3360	220	93	5.8	6.6
				11/06/76	1530		142	2800	120	95	5.4	5.7
			SLURRY FROM SPRAY TOWER	11/02/76	2330		132	3480	460	85	5.5	6.3

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
1	VST	VFG-1D	SLURRY FROM SPRAY TOWER	11/03/76	0730		94	3080	940	65	5.6	4.3
				11/03/76	1530		137	2880	270	90	5.7	5.5
				11/03/76	2330		126	3040	300	89	6.2	5.7
				11/04/76	0730		142	3080	330	89	6.5	5.8
				11/04/76	1530		141	3600	400	85	5.5	6.7
				11/04/76	2330		148	3440	300	90	5.0	6.6
				11/05/76	0730		150	3530	260	92	5.2	7.2
				11/05/76	1530		143	2920	160	94	6.7	5.8
				11/05/76	2330		156	3120	160	94	4.0	6.2
				11/06/76	0730		149	3360	220	93	5.9	6.6
				11/06/76	1530		142	2800	120	95	5.4	5.7
		VFG-1E	SLURRY TO SPRAY TOWER	11/06/76	2330	Z	140	3160	440	85	5.5	11.2
				11/07/76	0730		80	3240	980	66	10.2	9.0
				11/07/76	1530		110	3600	1140	65	7.6	9.8
				11/07/76	2330		153	2880	760	71	6.9	8.5
				11/08/76	0730		149	3120	760	73	6.5	9.5
				11/08/76	1530		151	3240	680	77	7.5	10.4
				11/08/76	2330		155	3400	780	75	5.0	10.6
				11/09/76	0730		146	3600	930	72	6.2	10.9
				11/09/76	1530		153	3040	720	74	4.3	9.4
				11/09/76	2330		156	2920	660	75	5.7	9.1
				11/10/76	0730		152	2760	740	70	5.0	8.1
				11/10/76	1530		155	3060	850	69	4.7	8.8
			SLURRY FROM SPRAY TOWER	11/06/76	2330	Z	140	3160	440	85	5.5	11.2
				11/07/76	0730		80	3240	980	66	10.2	9.0
				11/07/76	1530		110	3600	1140	65	7.6	9.8
				11/07/76	2330		153	2880	760	71	6.9	8.5
				11/08/76	0730		149	3120	760	73	6.5	9.5
				11/08/76	1530		151	3240	680	77	7.5	10.4
				11/08/76	2330		155	3400	780	75	5.0	10.6
				11/09/76	0730		146	3600	900	72	6.2	10.9
				11/09/76	1530		153	3040	720	74	4.3	9.4
				11/09/76	2330		156	2920	660	75	5.7	9.1
				11/10/76	0730		152	2760	740	70	5.0	8.1
				11/10/76	1530		155	3060	850	69	4.7	8.8
		VFG-1F	SLURRY TO SPRAY TOWER	11/10/76	2330	Z	154	3640	1700	48	4.8	21.7
				11/11/76	0730		149	3600			5.5	
				11/11/76	1530		152	3520	2520	21	5.3	8.9
				11/11/76	2330		142	3520	2520	21	6.0	8.9
				11/12/76	0730		152	3720	2640	21	5.5	9.8
				11/12/76	1530		155	3160	2120	26	5.5	10.0
				11/12/76	2330		152	3480	2440	22	7.1	9.5
				11/13/76	0730		152	3840	2760	20	6.5	9.5
				11/15/76	1530		154	3690	2460	26	4.7	11.7
				11/15/76	2330		153	3160	2160	24	6.1	9.4

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
1	VST	VFG-1F	SLURRY TO SPRAY TOWER	11/15/76	2330		153	3160	2160	24	8.1	9.4
				11/16/76	0730		155	3320	2320	22	5.7	9.2
				11/16/76	1530		153	3240	2240	23	5.5	9.3
				11/16/76	2330		155	3280	2280	23	6.0	9.3
				11/17/76	0730		154	3200	2160	25	5.3	9.9
				11/17/76	1530		155	3160	2120	26	5.2	10.0
				11/17/76	2330		155	2680	1780	26	5.5	8.7
				11/18/76	0730		155	2400	1520	30	5.5	8.8
			SLURRY FROM SPRAY TOWER	11/10/76	2330	Z	154	3640	1700	48	4.8	21.7
				11/11/76	0730		149	3600			5.5	
				11/11/76	1530		152	3520	2520	21	5.3	8.9
				11/11/76	2330		142	3520	2520	21	6.0	8.9
				11/12/76	0730		152	3720	2640	21	6.5	9.8
				11/12/76	1530		155	3160	2120	26	5.5	10.0
				11/12/76	2330		152	3480	2440	22	7.1	9.5
				11/13/76	0730		152	3840	2760	20	6.5	9.6
				11/15/76	1530		154	3680	2460	26	4.7	11.7
				11/15/76	2330		153	3160	2160	24	8.1	9.4
					2330		153	3160	2160	24	8.1	9.4
				11/16/76	0730		155	3320	2320	22	5.7	9.2
				11/16/76	1530		153	3240	2240	23	5.5	9.3
				11/16/76	2330		155	3280	2280	23	6.0	9.3
				11/17/76	0730		154	3200	2160	25	5.3	9.9
				11/17/76	1530		155	3160	2120	26	5.2	10.0
				11/17/76	2330		155	2680	1780	26	5.5	8.7
				11/18/76	0730		155	2400	1520	30	5.5	8.8
		VFG-1G	SLURRY TO SPRAY TOWER	11/18/76	1730	Z	152	2080	100	95		7.3
				11/18/76	2330	Z	149	2860	320	88	4.2	9.3
				11/19/76	0800		153	3200	500	83		9.8
				11/19/76	1530		124	3040	540	80	5.1	9.1
				11/19/76	2330		101	3240	540	81	5.5	9.8
				11/20/76	0730		141	3400	620	80	5.3	10.1
				11/20/76	1530		148	3080	540	81	5.6	9.2
				11/20/76	2330		152	3200	600	79	5.2	9.4
				11/21/76	0730	Z	148	3280	520	82	4.8	10.0
			SLURRY FROM SPRAY TOWER	11/18/76	1730	Z	152	2080	100	95		7.3
				11/18/76	2330	Z	149	2860	320	88	4.2	9.3
				11/19/76	0800		153	3200	500	83		9.8
				11/19/76	1530		124	3040	540	80	5.1	9.1
				11/19/76	2330		101	3240	540	81	5.5	9.8
				11/20/76	0730		141	3400	620	80	5.3	10.1
				11/20/76	1530		148	3080	540	81	5.6	9.2
				11/20/76	2330		152	3200	600	79	5.2	9.4
				11/21/76	0730	Z	148	3280	520	82	4.8	10.0
		VFG-1I	SLURRY TO SPRAY TOWER	11/22/76	1700		150	3000	460	83	5.7	9.2

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
1	VST	VFG-1I	SLURRY TO SPRAY TOWER	11/22/76	2330		152	3400	520	83	5.5	10.5
				11/23/76	0730		152	3400	580	81	4.8	10.2
				11/23/76	1530		152	3080	500	82	4.6	9.4
				11/23/76	2330		140	2880	460	82	4.7	8.8
				11/24/76	0730		101	2800	380	85	6.4	8.8
				11/24/76	1530		144	2600	420	82	5.8	7.9
				11/24/76	2330		150	3240	720	75	5.7	9.1
				11/25/76	0730		151	3200	620	78	4.5	9.3
				11/25/76	1530		142	2920	580	78	7.0	8.4
				11/25/76	2330		130	2800	580	77	6.2	8.0
				11/26/76	0730		145	3120	720	74	4.3	8.6
				11/26/76	1530		144	3200	690	76	4.0	9.0
				11/26/76	2330		142	3320	900	70	3.4	8.6
				11/27/76	0730		148	3720	880	74	3.8	10.2
			SLURRY FROM SPRAY TOWER	11/22/76	1700		150	3000	460	83	5.7	9.2
				11/22/76	2330		152	3400	520	83	5.5	10.5
				11/23/76	0730		152	3400	580	81	4.8	10.2
				11/23/76	1530		152	3080	500	82	4.6	9.4
				11/23/76	2330		140	2880	460	82	4.7	8.8
				11/24/76	0730		101	2800	380	85	6.4	8.8
				11/24/76	1530		144	2600	420	82	5.8	7.9
				11/24/76	2330		150	3240	720	75	5.7	9.1
				11/25/76	0730		151	3200	620	78	4.5	9.3
				11/25/76	1530		142	2920	580	78	7.0	8.4
				11/25/76	2330		130	2800	580	77	6.2	8.0
				11/26/76	0830		145					
				11/26/76	1530		144	3200	690	76	4.0	9.0
				11/26/76	2330		142	3320	900	70	3.4	8.6
				11/27/76	0730		148	3720	880	74	3.8	10.2
		VFG-1P	SLURRY TO SPRAY TOWER	11/27/76	1530	Z	90	2930	940	69	4.0	9.5
				11/27/76	2330	Z	150	3160	900	58	3.8	10.4
				11/28/76	0730	Z	150	3880	1480	59	4.3	10.3
				11/28/76	1530		150	3120	1050	63	5.8	9.4
				11/28/76	2330		148	2840	780	70	5.2	9.5
				11/29/76	0730		149	2600	760	68	6.0	8.5
				11/29/76	1530		140	2960	880	67	6.0	9.6
				11/29/76	2330		146	2400	680	69	6.6	7.9
				11/30/76	0730		146	2920	940	64	7.3	9.0
					0730		146	2920	940	64	7.3	9.0
				11/30/76	1530		149	2820	800	69	7.0	9.3
				11/30/76	2330		150	3000	1000	63	5.3	9.1
				12/01/76	0730		142	3360	1200	60	5.1	9.8
				12/01/76	1530		100	3040	960	69	7.0	10.0
				12/01/76	2330		146	3440	1140	63	6.0	10.5
				12/02/76	0730		144	3440	1180	62	7.5	10.3

GAS ANALYSES

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                                                                        BOIL                                MAKE
                                                                  GAS/  LOAD   SO2   SO2  SO2     O2       PER
SCR  SYS-  RUN                                                    TIME  MEGA   IN    OUT  REM     IN       PASS
NO.  TEM   NO.     SAMPLE NAME               DATE       TIME  FLAG  WATT   PPM   PPM   %      %       MMOL/L
---  ----  ------  ------------------------  --------   ----  ----  ----   ----  ----  ---   ----     ------
  1  VST   VFG-1P  SLURRY TO SPRAY TOWER     12/02/76   1530         147   3200   900  69               10.6
                                             12/02/76   2330         140   3480  1060  66               11.1
                                             12/03/76   0730         142   3720  1300  61               11.0
                                             12/03/76   1530         144   3520  1100  65               11.1
                                             12/03/76   2330         147   3880  1540  56               10.5
                   SLURRY FROM SPRAY TOWER   11/27/76   1530  Z       90   2900   840  68    4.0         9.5
                                             11/27/76   2330  Z      150   3160   900  68    3.8        10.4
                                             11/28/76   0830  Z      150
                                             11/28/76   1530         150   3120  1050  63    5.8         9.4
                                             11/28/76   2330         149   2840   780  70    5.2         9.5
                                             11/29/76   0730         149   2600   750  68    6.0         8.5
                                             11/29/76   1530         140   2960   880  67    6.0         9.6
                                             11/29/76   2330         146   2400   690  69    6.6         7.9
                                             11/30/76   0730         145   2920   940  64    7.3         9.0
                                                        0730         146   2920   940  64    7.3         9.0
                                             11/30/76   1530         149   2820   800  69    7.0         9.3
                                             11/30/76   2330         150   3020  1000  63    5.3         9.1
                                             12/01/76   0730         142   3360  1200  60    5.1         9.8
                                             12/01/76   1530         100   3040   860  69    7.0        10.0
                                             12/01/76   2330         146   3440  1140  63    6.0        10.5
                                             12/02/76   0730         144   3440  1180  62    7.5        10.3
                                             12/02/76   1530         147   3200   900  69               10.6
                                             12/02/76   2330         140   3480  1060  66               11.1
                                             12/03/76   0730         142   3720  1300  61               11.0
                                             12/03/76   1530         144   3520  1100  65               11.1
                                             12/03/76   2330         147   3880  1540  56               10.5
                   SLURRY AT TCA OUTLET      11/29/76   0700
                                                        0700
                                             11/30/76   0700
                                                        0700
                                                        0700
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LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
629-1A	1816	04/28/76	2330		6.00	848	3099	33	80	339	8211	8618	3545	16155	98	51	7.1
		04/29/76	0730	X	6.28	782	1744	43	85	180	5986	6202	2127	19947	101	51	-1.4
		04/29/76	1530		6.08	223	5219	42	87	2216	12997	15656	3368	24152	28	50	5.3
		04/29/76	2330	TS	5.98	236	5074	46	64	1718	16202	18264	3999	27240	37	52	-13.3
		04/30/76	0730		6.04	261	5349	42	64	2171	12834	15439	3990	24621	32	50	5.5
		04/30/76	1530		6.00	764	4579	50	81	1945	12424	14758	3722	23565	98	51	1.5
		04/30/76	2330		6.07	683	4599	50	70	882	13619	14677	3722	23625	95	52	1.4
		05/01/76	0730		6.04	358	4559	40	70	1334	11784	13385	3385	21530	46	54	5.6
		05/03/76	2330		5.66	574	4399	36	64	361	12721	13154	3013	21168	78	52	8.9
		05/04/76	0730		6.15	685	4059	44	69	678	11047	11861	3190	19772	87	50	9.4
		05/04/76	1530		6.00	678	4409	50	56	633	12952	13712	3369	22146	93	51	4.7
		05/04/76	2330		6.02	505	4459	42	64	949	11444	12623	3368	20892	63	52	9.7
		05/05/76	0730		5.83	413	4139	40	87	949	10069	11208	3013	19690	49	50	12.2
		05/05/76	1530		6.02	936	3133	39	85	361	9469	9902	3545	17524	114	50	0.1

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
629-1A	1816	05/05/76	2330		5.91	752	2979	43	71	90	8615	8723	3368	16118	96	53	1.9
		05/06/76	0730		5.99	750	2809	40	86	678	8000	8814	3368	15733	92	50	-2.2
		05/06/76	1530		5.99	884	2929	50	106	452	7728	8270	3368	15517	100	50	7.9
		05/06/76	2330		6.00	641	3299	46	86	588	8544	9250	3368	16572	76	51	6.5
		05/07/76	0730		6.03	496	3139	58	89	723	8154	9022	3545	16204	59	50	0.0
		05/07/76	1530	TS	6.02	720	3069	43	82	723	4156	5024	3013	11206	47	52	35.2
		05/08/76	0730		6.04	394	3309	46	86	1017	8269	9489	3545	16566	46	50	-0.5
		05/08/76	1530	TS	6.06	474	3199	40	97	882	10757	11815	3190	16639	71	52	-15.4
		05/08/76	2330		5.99	772	3529	42	101	723	9361	10229	4254	18782	92	50	0.1
		05/09/76	0730		5.74	924	3099	41	99	859	8644	9675	4609	18275	111	50	-8.5
		05/09/76	1530		6.14	916	3819	46	103	633	8502	9262	4963	18982	94	50	8.7
		05/09/76	2330		6.07	508	3809	43	104	814	8599	9576	4963	18840	55	50	1.1
		05/10/76	0730		5.93	476	3499	45	97	791	8007	8956	4786	17703	52	50	-1.7
		05/10/76	1530		5.64	854	3359	46	86	859	7993	9024	4609	17806	91	52	1.6
		05/10/76	2330		6.10	882	3239	55	93	542	8916	9566	4786	18513	106	50	-6.0
		05/11/76	0730		5.87	640	3589	52	96	768	7674	8596	5140	17959	65	50	2.4
		05/11/76	1530	MG	6.00	561	2859	52	94	768	7883	8805	4786	17043	68	52	-17.4
		05/11/76	2330		6.12	640	3459	35	81	588	6803	7509	5140	16746	40	50	5.9
		05/12/76	0730	Y	5.90	401	4239	96	122	1334	7975	9576	5140	19309	58	51	8.5
	1818	05/07/76	0730		6.73												
		05/10/76	0730		6.21												
	1821	04/30/76	1530														
		05/07/76	1530														
		05/10/76	1530														
630-1A	1816	05/12/76	1530	X	7.06	69	3699	123	103	1899	8755	11034	4609	19257	8	52	-13.9
		05/12/76	2330	X	6.94	73	4009	37	86	1899	7983	10262	5495	19582	8	50	-9.3
		05/13/76	0730		6.92	525	3659	106	104	361	8925	9358	5761	19441	61	51	-6.8
		05/13/76	1530		7.12	600	3659	62	91	183	10220	10436	5938	20750	77	52	-14.5
		05/13/76	2330		6.75	323	4319	101	100	407	8100	8588	5250	19200	31	50	9.1
		05/14/76	0730		7.02	346	4139	86	211	723	8338	9206	5672	19515	35	51	4.2
		05/14/76	1530	NA	7.03	258	4039		87	520	7429	8053	5672	18005	24	53	5.7
		05/14/76	2330		6.91	229	4179	58	89	678	7817	8631	6027	19077	22	50	2.9
		05/15/76	0730		6.17	262	4079	91	118	497	7892	8488	5495	18434	26	51	6.7
		05/15/76	1530		7.04	152	4049	50	88	859	6695	7726	5318	17211	13	51	9.9
		05/15/76	2330		7.07	208	4949	63	87	316	7274	7653	6381	19278	17	50	19.7
		05/16/76	0730		6.95	316	3839	51	93	316	7782	8161	5850	18247	32	51	0.4
		05/16/76	1530		7.03	226	3979	47	92	689	6354	7161	5672	17059	19	53	9.8
		05/16/76	2330		6.99	207	3829	57	88	452	7068	7610	5850	17551	20	50	2.0
		05/17/76	0730		7.03	167	4069	86	119	768	7130	8052	5140	17479	15	51	10.6
		05/17/76	1530		7.04	106	3419	36	73	995	7089	8283	4609	16327	11	52	-4.3
		05/17/76	2330		7.08	200	3179	44	76	1492	5910	7700	4963	15864	19	50	-9.0
		05/18/76	0730		7.04	159	3509	40	89	768	7557	8479	6027	18149	17	52	-15.3
	1818	05/14/76	0730		7.75												
		05/17/76	0730		7.36												
	1821	05/14/76	1530														

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
630-1A	1821	05/17/76	1530														
631-1A	1816	05/18/76	1530		7.02	800	3539	35	75	203	8037	8281	5672	18361	84	50	0.6
		05/18/76	2330		6.95	762	4159	37	87	135	8545	8707	7090	20815	75	51	0.7
		05/19/76	0730		7.04	552	4139	40	87	271	8373	8593	6736	20198	55	50	0.3
		05/19/76	1530		7.03	675	4269	50	86	407	8380	8858	6559	20426	65	50	5.0
		05/19/76	2330		7.00	1182	4259	48	85	113	8464	8630	7258	21419	110	51	7.2
		05/20/76	0730		6.94	622	4049	57	79	294	7072	7425	6381	19553	54	50	9.2
		05/20/76	1600		6.92	535	3569	45	80	429	5806	6321	6027	16491	43	50	7.0
		05/20/76	2330		6.98	109	4649	49	81	180	9446	9662	6736	21250	12	52	0.2
		05/21/76	0730		6.95	136	4449	44	89	1221	7446	8911	5743	19098	9	50	7.5
		05/21/76	1530		6.79	317	4749	42	84	814	7975	6952	7266	21249	28	50	4.7
		05/21/76	2330		7.04	290	5279	45	94	589	8000	6707	7830	22097	24	51	11.4
		05/22/76	0730		6.95	908	4559	45	79	316	8319	8698	7600	21826	81	50	6.8
		05/22/76	1530		7.00	756	4959	42	81	452	7569	8231	8863	22792	61	50	5.4
		05/22/76	2330		7.12	874	4649	48	86	271	8276	8601	8509	22713	77	51	2.6
		05/23/76	0730		6.96	900	5309	57	80	180	9118	9334	8863	24507	79	50	8.6
		05/23/76	1530		6.99	147	4919	45	85	1130	6628	7964	3331	21285	11	50	3.5
		05/23/76	2330		6.94	321	5959	50	81	1221	6341	10405	9041	25544	27	51	6.6
		05/24/76	0730		6.99	674	4739	80	64	452	9323	9865	9218	24550	65	50	-8.5
	1821	05/21/76	1530														
		05/24/76	0730														
632-1A	1816	05/28/76	2330		6.73	424	4009	58	77	407	6301	6789	7445	18721	34	50	1.2
		05/29/76	0730		6.99	170	5459	56	84	949	6080	7219	8509	21307	11	51	15.5
		05/29/76	1530		6.86	193	5179	57	84	859	7569	9600	8509	22450	15	51	4.9
		05/29/76	2330		7.08	158	4509	59	90	1311	7178	8751	7445	20750	13	50	-2.0
		05/30/76	0730		7.06	142	4319	54	96	1221	5543	7308	7268	19143	9	54	14.1
		05/30/76	1530		7.04	182	4909	50	89	914	7836	8813	7090	20970	16	50	8.1
		05/30/76	2330		7.14	210	4219	53	88	814	7190	8167	7090	19664	19	50	-2.2
		05/31/76	0730		7.04	216	4649	51	84	814	6986	7963	7030	19830	17	50	8.0
		05/31/76	1530		7.00	247	4599	53	92	859	7888	8919	7530	20828	22	51	2.4
		05/31/76	2330		7.00	433	4539	55	104	497	7677	8273	6331	19626	38	50	12.0
		06/01/76	0730		7.36	461	4489	51	98	407	7752	8240	7268	20526	41	50	5.2
		06/01/76	1530		6.95	214	4059	55	82	316	8009	8388	6559	19294	22	51	-3.0
		06/01/76	2330		7.03	145	4219	57	75	316	7682	9061	6381	18879	14	50	3.1
		06/02/76	0730		7.00	212	4759	52	81	791	7205	8154	7090	20190	17	50	9.0
		06/02/76	1530		7.04	215	4509	53	78	904	7196	8291	6559	19514	16	51	7.4
		06/02/76	2330		6.91	209	4369	55	84	678	7043	7857	6736	19194	18	50	6.0
		06/03/76	0730		6.90	141	4579	50	89	746	7209	8104	6913	19727	12	50	6.3
		06/03/76	2300		6.45	153	4709	42	108	1402	8193	9875	6736	21343	14	51	1.0
	1818	05/28/76	2330														
		05/29/76	2330		7.32												
		05/30/76	2330		7.23												
	1821	05/29/76	0730														
		05/30/76	0730														
		05/31/76	0730														

LIQUID ANALYSES

RUN NC.	ANALY TICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SUL-FATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
633-1A	1816	06/05/76	1530	X	6.99	203	3459	38	89	678	7353	8167	5318	17138	22	50	-7.2
		06/05/76	2330		7.10	117	4489	38	101	1311	7240	8813	5850	19146	10	52	8.1
		06/06/76	0730		7.04	110	4369	37	97	1492	7553	9343	5318	18976	10	50	6.6
		06/06/76	1530		7.02	88	3789	38	104	1945	8073	10407	5318	19355	10	50	-14.4
		06/06/76	2330		7.02	83	3809	36	101	1945	6055	8399	4963	16992	7	50	2.2
		06/07/76	0730		7.06	131	4289	39	98	1718	8502	10564	4963	19740	13	50	1.0
		06/07/76	1530		7.12	118	4649	38	118	2103	8891	11415	4786	20703	12	50	5.2
		06/07/76	2330		7.14	125	4519	43	100	1017	7859	9079	5318	18931	12	50	11.4
		06/08/76	0730		7.08	115	4039	50	81	1130	7563	8919	4609	17587	11	50	7.8
		06/08/76	1530		7.20	224	3799	37	93	927	9496	10608	4431	19007	27	50	-5.5
		06/08/76	2330		7.03	135	3929	35	94	768	7881	8803	5140	17982	14	50	1.7
		06/09/76	0730		7.08	135	4359	38	90	904	9001	10086	5052	19579	14	50	4.6
		06/09/76	1530		6.95	161	3809	41	93	995	8672	9866	4963	18739	18	50	-6.0
		06/09/76	2330		7.02	181	3829	40	101	768	7457	8379	4786	17162	18	50	5.8
		06/10/76	0730		6.87	210	3579	38	94	633	8477	9237	4520	17551	24	51	-3.5
		06/10/76	1530		6.87	163	3899	41	90	972	8487	9653	4786	18438	18	52	-0.3
		06/10/76	2330		7.28	543	3819	48	94	271	8161	8486	5950	18706	56	50	1.2
		06/11/76	0730		7.14	569	3919	39	90	429	8616	9131	5406	19068	67	51	3.4
		06/11/76	1530		6.86	206	4279	41	93	723	9013	9881	5406	19761	22	55	2.3
		06/11/76	2330	MG	7.70	159	3329	44	96	904	7612	8697	5140	17284	18	50	-13.9
		06/12/76	0730		6.98	109	4219	38	93	1447	9197	10933	4786	19889	12	50	-1.7
		06/12/76	1530		6.87	104	4259	39	93	1357	9305	10933	4963	20120	12	54	-2.2
		06/12/76	2330		7.00	169	3969	40	96	746	7339	8234	5140	17439	16	50	6.7
		06/13/76	0730	MG	7.12	146	3499	51	90	859	8355	9986	4609	18209	18	51	-12.8
		06/13/76	1530	MG	6.91	102	4329	38	90	1289	6863	8410	5140	17851	9	54	12.4
		06/13/76	2330	MG	7.07	82	4379	36	91	1515	7256	9074	4786	18145	7	50	12.0
		06/14/76	0530		6.96	117	3869	43	104	1130	7684	9240	4786	17733	12	50	1.7
	1818	06/07/76	0730		7.62												
	1821	06/07/76	1530														
		06/11/76	1530														
634-1A	1816	06/20/76	0730		8.12	1608	28	12	5	54	1805	1870	2127	5639	143	52	-18.9
		06/20/76	1530		8.14	1356	152	14	5	45	691	745	2038	4301	51	50	9.8
					8.14												
		06/20/76	2330		7.91	1420	133	16	6	45	1354	1408	1950	4924	98	52	-2.0
					7.91												
		06/21/76	0730		8.04	1536	103	9	5	18	1554	1576	2127	5352	116	50	-8.4
		06/21/76	1530		7.99	1669	153	21	5	22	960	985	2491	5310	73	50	6.6
		06/21/76	2330		8.04	1736	139	13	6	27	1092	1124	2659	5672	84	52	0.4
		06/22/76	0730		8.09	1823	155	13	6	113	725	861	3456	6296	57	52	-10.2
		06/22/76	1530	CA	8.03	1632	171	23	5	45	418	472	3722	6016	32	50	-18.8
					8.03											50	
		06/22/76	2330		8.10	2108	167	14	29	18	274	296	3545	6155	23	50	11.7
					8.10												
		06/23/76	0730		8.06	2404	197	17	10	67	559	639	4377	7331	45	53	6.5
		06/23/76	1530		8.08	1812	163	19	9	22	350	376	3998	6363	28	50	-14.7

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
634-1A	1816	06/23/76			8.08												
		06/23/76	2330		8.00	2280	205	17	41	36	1428	1471	3722	7729	110	50	-2.4
					8.00												
		06/24/76	0730		7.66	2464	256	16	10	45	1964	2018	3811	9566	146	54	-3.1
					7.66												
		06/24/76	1530	CA	7.96	3230	358	16	10	67	1759	1839	3722	9162	135	51	25.2
					7.96												
		06/24/76	2330		8.06	2320	247	11	10	27	1818	1850	3722	8155	134	50	-4.9
					8.06												
		06/25/76	0730		7.91	2216	273	14	11	22	1246	1272	3722	7504	92	54	1.9
					9.56												
		06/25/76	1530		8.02	1800	262	15	10	90	532	640	3900	6609	39	53	-9.8
		06/25/76	2330		8.06	1760	263	16	48	45	261	315	3362	5761	19	50	8.8
		06/26/76	0730		7.95	1992	391	15	12	67	1358	1438	3534	7469	91	54	0.1
		06/26/76	1530		7.95	2024	373	17	12	23	2220	2248	3190	7859	145	50	-3.0
		06/26/76	2330		7.93	2176	395	18	13	36	1954	1997	3722	8314	131	50	-3.1
		06/27/76	0730		7.94	2530	587	16	12	67	1853	1933	3722	8787	120	53	17.3
		06/27/76	1530		7.89	2210	384	17	11	45	2174	2228	3456	8297	145	53	-0.7
		06/27/76	2330		8.04	2450	396	14	13	45	1817	1871	3403	8178	127	53	13.4
		06/28/76	0730		7.96	2380	480	14	14	31	1833	1870	3545	8297	122	55	12.7
		06/28/76	1530		8.02	2460	585	18	12	45	2994	3048	3722	9836	184	53	2.1
		06/28/76	2330		8.08	2140	451	13	13	94	2282	2395	3545	8538	145	50	-3.5
		06/29/76	0730		8.11	2040	459	15	14	180	2765	2981	3369	8840	169	50	-11.8
		06/29/76	1530		8.09	2060	419	14	13	180	2285	2501	3545	8516	146	53	-10.0
		06/29/76	2330		7.82	1695	451	17	13	13	1706	1722	3190	7085	102	54	-2.5
		06/30/76	0730		8.16	1630	425	19	13	90	1571	1679	3190	6938	95	50	-6.4
		06/30/76	1530		9.00	2030	470	22	14	135	1813	1975	3013	7497	114	52	10.7
		06/30/76	2330		7.86	1510	518	20	13	54	1132	1197	3279	6526	64	54	1.5
		07/01/76	0730		8.03	1530	451	21	13	226	338	609	4077	6656	21	50	-11.3
					8.03												
		07/01/76	1530		7.95	1690	439	22	12	90	837	945	4343	7433	53	52	-16.8
		07/01/76	2330		8.10	1735	488	21	13	54	480	545	4165	6956	30	53	-0.7
		07/02/76	0730		8.07	1565	434	20	12	113	283	419	4165	6592	18	50	-9.8
				SO2	8.07	1565	434	20	12	225	128	399	4165	6550	8	50	-9.4
		07/02/76	1530		8.07	2070	463	23	10	99	1025	1144	3722	7412	68	50	9.7
	1818	25/76/06			8.56												
		06/22/76	2330														
		06/25/76	0730		8.56											46	
		06/28/76	0730		8.53												
		07/02/76	0730		8.20												
	1820	04/23/75	0700		7.20	2790	303	61	117	48	1524	1582	5105	9948	116	40	-4.2
	1821	06/23/76	0730														
		06/25/76	1530														
		07/02/76	1530														
635-1A	1816	07/10/76	2330		8.19	2350	680	20	19	135	1671	1833	4786	9661	102	52	0.8

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
635-1A	1816	07/17/76	0730		8.15	2330	753	24	18	67	1746	1826	4963	9901	102	50	1.0
		07/17/76	1530		8.08	2370	712	23	18	67	2003	2083	5052	10245	119	50	-4.2
		07/17/76	2330		8.07	2520	731	24	17	45	2369	2423	4609	10315	142	52	3.7
		07/18/76	0730		8.16	2000	641	20	19	90	2202	2310	4254	9226	125	50	-9.2
		07/20/76	0730		8.45	2130	515	25	23	36	673	716	4165	7567	44	52	11.9
		07/20/76	1530		8.11	2120	642	29	23	226	339	410	5140	8519	21	50	1.7
		07/20/76	2330		8.12	2470	563	26	14	90	1005	1113	5140	9308	67	50	1.7
		07/21/76	0730		8.20	1955	602	17	17	113	833	969	4431	7968	51	54	2.1
		07/21/76	1530		8.07	2040	591	34	24	90	670	778	4875	8324	42	50	-0.8
		07/21/76	2330		8.17	2070	589	14	11	45	1064	1138	4786	8599	67	51	-4.0
		07/22/76	0730		8.04	1985	667	19	21	113	1107	1243	4431	8343	65	55	2.9
		07/22/76	1530		7.95	1890	601	24	22	135	784	946	4343	7799	47	50	2.2
		07/22/76	2330		8.08	2020	643	16	16	90	1319	1427	4077	8191	78	50	6.5
		07/23/76	0730		8.08	2460	663	19	22	54	2442	2507	4254	9914	148	54	3.6
		07/23/76	1530		6.32	2330	699	19	21	226	1689	1960	4077	9061	102	52	11.0
		07/23/76	2330	CA	8.11	2899	615	18	15	90	2286	2394	4077	10000	151	50	16.1
		07/24/76	0730		8.16	2365	643	18	21	81	1757	1854	4254	9139	109	54	7.9
		07/24/76	1530		7.89	2210	579	21	17	180	1595	1811	4254	8856	99	52	1.0
		07/24/76	2330		8.04	2500	573	20	71	113	1797	1933	4963	10037	117	50	-3.2
		07/25/76	0730		8.02	2679	685	21	21	54	1852	1917	4875	10187	118	54	7.4
		07/25/76	1530		7.98	2510	634	20	22	67	1752	1832	4975	9880	111	50	1.8
		07/25/76	2330		8.00	2640	641	19	19	67	1790	1870	5300	10476	115	50	-1.4
				MG	8.00	2640	1153	19	19	67	1789	1869	5318	11005	95	50	17.1
		07/26/76	0730		7.95	2040	657	20	20	67	1900	1980	4520	9224	109	53	-7.3
	1921	07/17/76	1530														
		07/20/76	1530														
		07/21/76	1530														
		07/22/76	1530														
		07/23/76	1530														
		07/24/76	1530														
		07/25/76	1530														
636-1A	1816	07/26/76	1530		8.07	2596	629	22	22	180	1633	1849	4963	10045	106	52	2.4
		07/28/76	2330		8.24	2415	651	20	22	22	1574	1600	4520	9224	98	54	8.4
		07/29/76	0730		8.08	2410	637	22	22	22	1668	1694	4786	9567	104	50	2.3
		07/29/76	1930		8.10	2619	677	22	20	90	1830	1938	4520	9778	116	52	10.7
		07/29/76	2330		8.10	2420	647	19	21	36	1938	1981	4609	9690	120	54	2.3
		07/30/76	0730		7.89	2569	620	20	20	90	1913	2021	4609	9841	122	50	4.7
		07/30/76	1530		8.03	2690	597	14	16	90	2020	2128	4254	9681	132	50	10.9
		07/30/76	2330		7.93	2380	667	20	22	22	1680	1706	4520	9311	103	54	6.9
		07/31/76	0730		7.99	2360	647	22	22	45	2072	2126	4609	9777	126	50	-1.0
		07/31/76	1530		8.10	2530	645	22	22	75	1781	1871	4325	9400	113	50	11.0
					8.10	2530	645	22	22	126	1208	1359	4325	8878	78	50	16.9
		07/31/76	2330		7.99	2260	683	21	22	36	1938	1981	4254	9214	115	53	5.4
		08/01/76	0730		7.87	2240	667	19	20	67	1655	1735	4431	9099	99	50	4.1
		08/01/76	1530		7.79	2100	655	17	20	67	1731	1811	4077	8567	102	52	4.5

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
636-1A	1816	08/01/76	2330		7.95	2150	689	18	21	67	1541	1621	4165	8651	90	53	8.5
					7.95	2150	689	18	21	67	1627	1707	4165	8737	95	53	7.4
		08/02/76	0730		8.03	1880	646	21	20	226	697	968	4254	7744	41	50	5.5
		08/02/76	1530		8.06	1635	605	23	23	65	744	822	4077	7172	42	50	0.6
				CA	8.06	2480	605	23	23	45	1484	1538	4077	8737	95	50	16.0
		08/02/76	2330		7.93	1635	667	22	23	22	838	864	3900	7107	46	50	7.3
		08/03/76	0730		7.99	1640	660	20	22	67	889	969	4077	7375	48	52	1.7
		08/03/76	1530		8.07	1528	543	21	21	113	622	758	3900	6848	34	50	3.7
		08/03/76	2330		7.93	1499	638	20	14	49	499	547	3988	6689	27	50	3.3
		08/04/76	0730		8.08	1525	665	24	46	45	936	990	3900	7141	49	52	1.8
		08/04/76	1130		8.03	1610	653	24	23	135	1101	1263	3545	7091	59	50	6.9
	1821	07/26/76	1530														
		07/29/76	1930														
		07/30/76	1530														
		07/31/76	1530														
		08/01/76	1530														
		08/02/76	1530														
		08/03/76	1530														
		08/04/76	1130														
637-1A	1816	08/06/76	1930		8.04	1545	635	15	20	45	1505	1559	3279	7044	79	53	4.0
		08/06/76	2330		6.57	1300	539	15	20	45	1125	1179	2925	5969	59	50	3.0
		08/07/76	0730		7.99	1200	564	22	24	90	1241	1349	2747	5888	61	52	2.1
		08/07/76	1530		8.07	1385	669	9	13	67	1690	1770	3456	7238	81	55	-7.6
		08/07/76	2330		8.04	1690	625	14	18	67	1690	1770	3368	7472	92	55	3.6
		08/08/76	0730		8.79	1510	574	13	19	90	1262	1370	3279	6747	68	53	2.1
		08/08/76	1530		7.65	1890	613	14	17	90	1725	1833	3368	7717	99	55	8.7
		08/08/76	2330		7.79	1880	583	15	17	67	1552	1632	3368	7402	89	55	7.1
		08/09/76	0730		7.94	1610	588	19	16	316	1412	1791	3013	6974	78	52	5.9
		08/09/76	1530		8.62	1560	551	17	17	22	1491	1517	3545	7233	81	54	-3.7
		08/09/76	2330		7.51	1505	580	21	16	45	1156	1210	3456	6779	63	55	1.2
		08/10/76	0730	CL	7.94	1395	603	13	16	90	1239	1347	2659	6015	64	50	14.3
				CL	7.94	1425	597	12	17	65	1164	1242	2676	5556	61	50	16.4
		08/10/76	1530		7.96	1975	611	12	17	113	1740	1876	3722	8190	102	55	3.8
		08/10/76	2330		7.81	1870	538	22	15	158	1580	1770	3634	7917	90	51	5.3
		08/11/76	0730		7.96	1875	563	15	16	90	1671	1779	3651	7861	98	50	0.7
		08/11/76	1530		8.03	1640	623	12	17	22	1576	1602	3545	7435	85	54	0.5
		08/11/76	2330		7.95	1480	584	18	19	158	1180	1370	3368	6807	63	52	-0.3
		08/12/76	0730		8.00	1580	700	12	17	90	1387	1495	3545	7331	71	50	4.6
	1821	08/06/76	1930														
		08/07/76	1530														
		08/08/76	1530														
		08/09/76	1530														
		08/10/76	1530														
		08/11/76	1530														
638-1A	1816	08/16/76	1930		7.87	1400	491	18	14	135	1386	1548	3013	6457	76	51	-5.2

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
638-1A	1816	08/16/76	2330		7.77	1595	550	21	21	226	1746	2017	3279	7438	96	52	-6.5
		08/17/76	0730		7.91	1790	553	13	17	113	2094	2230	2925	7505	119	52	5.1
		08/17/76	1530		7.69	2230	564	16	18	90	2034	2142	3900	8852	126	54	2.7
		08/17/76	2330		7.87	2370	590	12	13	63	2215	2291	3545	8808	139	50	11.9
		08/18/76	0730		7.78	2000	579	17	14	226	1746	2017	3900	8492	104	52	-2.3
				TS	7.78	2000	579	17	14	226	2704	2975	3900	9440	155	52	-15.8
		08/18/76	1530		8.04	2140	546	19	15	180	2011	2227	3634	8545	124	54	2.7
		08/18/76	2330		8.07	2380	571	14	16	81	1963	2060	3545	8570	124	50	14.3
				MG	8.07	2380	705	14	16	76	1969	2060	3545	8705	118	50	19.6
		08/19/76	0530		7.87	2230	588	12	17	203	1964	2208	4077	9091	121	52	-0.2
		08/19/76	1600		8.16	2040	597	16	14	180	1714	1930	3900	8461	102	54	1.2
		08/19/76	2330		8.11	2270	637	10	16	159	1783	1973	4077	8951	109	50	6.3
		08/20/76	0730		7.95	2015	751	17	16	67	2086	2166	3722	8674	113	52	8.2
		08/20/76	1530		8.00	1715	643	16	14	67	2065	2145	3545	8065	110	52	-3.7
		08/20/76	2330		7.98	1610	673	6	16	36	2216	2259	3456	8013	112	50	-6.0
		08/21/76	0730		8.15	2065	651	9	17	22	2140	2166	3911	9715	127	54	3.1
		08/21/76	1530		7.83	1780	629	15	15	67	2065	2145	3768	7939	113	54	1.4
		08/21/76	2330	CA	8.00	2480	662	9	12	45	2237	2291	3722	9167	137	50	14.7
		08/22/76	0730		7.53	2295	699	9	17	90	2141	2249	3900	9061	131	54	5.2
		08/22/76	1530	CA	8.16	1472	689	12	15	271	1777	2102	3811	8047	97	52	-15.4
		08/22/76	2330	CA	8.12	2220	624	10	81	135	2076	2239	3368	8514	125	54	14.0
		08/23/76	0730		8.20	2090	604	8	78	158	1889	2079	3634	8461	113	54	5.7
		08/23/76	1530		7.96	2095	668	10	81	113	2391	2527	3722	9080	136	54	2.7
		08/23/76	2330		7.96	2090	696	9	12	54	2205	2270	3545	8611	124	50	9.2
		08/24/76	0530		7.95	1970	602	9	12	180	2043	2259	3456	8272	118	54	2.7
	1821	08/16/76	1930														
		08/17/76	1530														
		08/18/76	1530														
		08/19/76	1600														
		08/20/76	1530														
		08/21/76	1530														
		08/22/76	1530														
		08/23/76	1530														
639-1A	1816	08/24/76	1530	X	7.04	1020	1599	9	14	45	3004	3058	3634	9325	72	51	9.3
		08/24/76	2330		7.19	37	3109	7	15	1886	4703	6765	3102	12859	3	52	10.0
		08/25/76	0730		6.99	67	2759	8	15	1266	4591	6110	3545	12251	6	54	1.7
		08/25/76	1530		6.92	69	3459	9	13	2080	6977	9473	3456	16062	7	54	-2.1
					6.98	60	4139	9	14	3121	7299	11044	3279	17921	6	52	6.3
		08/26/76	0730		6.95	74	3709	8	13	1334	8253	9854	3279	16670	8	54	3.8
		08/26/76	1530		6.94	120	3439	6	15	836	8431	9454	2836	15683	15	51	4.5

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
639-1A	1816	08/26/76	2330		6.94	232	3599	6	16	226	8734	9005	3190	16003	28	54	10.0
		08/27/76	0730		6.91	638	3309	7	16	316	10370	10449	3102	17458	86	52	-0.1
		08/27/76	1530		7.03	610	3399	10	16	81	10214	10311	3013	17343	82	50	3.6
		08/27/76	2330		6.94	754	3299	8	17	407	9791	10279	2925	17201	98	52	4.3
					6.94											52	
		08/28/76	0730		6.94	732	3289	8	17	384	9592	10053	2936	16858	94	52	6.0
		08/28/76	1530		7.04	639	3309	9	12	452	9897	10439	2304	16622	85	52	7.4
		08/28/76	2330		7.12	774	3369	9	13	339	9638	10045	2925	17067	98	54	7.9
		08/29/76	0730		6.95	836	3589	7	16	588	9475	10181	2747	17258	99	51	14.3
		08/29/76	1530		6.98	998	2889	8	17	203	7386	8230	3722	15823	116	50	4.1
		08/29/76	2330		6.91	982	3279	10	16	158	8411	8601	3900	16756	110	53	9.6
		08/30/76	0730		6.91	929	3129	9	17	248	8068	8366	3900	15299	104	52	5.7
		08/30/76	1530		7.00	1000	3019	12	18	140	8073	8241	3900	15162	114	50	5.9
		08/30/76	2330		7.11	850	3269	10	17	271	7615	7940	4431	15463	89	52	7.0
		08/31/76	1530		6.96	876	3019	9	16	212	7656	7910	3722	15510	97	50	7.9
		08/31/76	2330		7.00	736	3049	10	17	90	7639	7747	3722	15263	82	54	7.7
		09/01/76	0530		7.00	1233	3299	11	17	135	8418	8580	4165	17168	136	52	9.3
	1821	08/24/76	1530														
		08/25/76	1530														
		08/26/76	1530														
		08/27/76															
		08/28/76	1530														
		08/29/76	1530														
		08/30/76	1530														
		08/31/76	1530														
640-1A	1816	09/02/76	1830		7.14	846	3189	12	16	90	8536	8644	4077	15766	99	50	3.5
		09/02/76	2330		7.00	782	3639	23	24	135	8759	8921	4520	17882	87	54	7.9
		09/03/76	0730		6.87	832	3189	11	14	45	8206	8260	3634	15931	95	51	9.9
		09/03/76	1530		7.00	740	3109	9	17	226	8586	8357	3900	16587	90	53	-0.3
		09/03/76	2330		6.96	486	3009	9	15	135	7436	7598	3634	14724	55	55	4.4
		09/04/76	0730		6.90	986	2809	10	16	180	7446	7662	3634	15081	110	54	6.8
		09/04/76	1530		6.95	832	3299	10	16	203	8157	8401	3900	16417	92	50	9.2
		09/04/76	2330	CL	6.95	888	3069	10	16	180	7937	8153	3013	15113	100	55	14.4
		09/05/76	0730		6.87	575	2969	11	16	122	7217	7363	3368	14278	64	54	9.3
		09/05/76	1530		6.95	508	3379	10	16	407	7878	8366	3279	15477	56	54	12.3
		09/05/76	2330		7.02	722	3189	9	15	135	8269	8431	3722	15061	84	54	6.2
		09/06/76	0730	CA	6.92	922	3229	10	15	90	8344	8452	3279	15989	104	54	14.1
		09/06/76	1530		6.87	730	2939	11	15	135	8375	8537	3279	15484	90	54	3.2
		09/06/76	2330		7.15	746	3079	10	16	135	8204	8366	3368	15558	88	54	7.6
		09/07/76	0730		7.00	486	2929	14	15	171	9049	9254	3013	15677	66	50	-4.3

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
640-1A	1816	09/07/76	1530		7.08	554	2939	9	15	226	8202	8473	3456	15401	69	55	-1.4
		09/07/76	2330		7.16	459	3479	8	17	407	7259	7747	3634	15253	46	51	14.9
		09/08/76	0730		7.18	782	2919	13	12	203	7091	7335	3190	14210	84	50	13.3
		09/08/76	1530		7.08	904	2889	12	12	45	7416	7470	4431	15709	100	54	1.1
		09/08/76	2330		7.04	810	3299	11	12	271	6996	7321	4343	15742	79	54	12.1
		09/09/76	0430		7.96	796	3159	13	11	180	7076	7292	3900	15135	81	50	12.9
	1821	09/03/76	1530														
		09/04/76	1530														
		09/05/76	1530														
		09/06/76	1530														
		09/08/76	1530														
641-1A	1816	09/09/76	1600	X	6.61	948	3239	12	12	180	7166	7382	4520	16677	100	52	6.7
		09/09/76	2330	X	7.02	942	3289	11	12	248	7001	7299	4520	16023	90	52	12.2
		09/10/76	0730	Y	6.95	1060	3979	12	17	45	6087	6141	6027	17227	78	50	21.9
		09/10/76	1530		7.06	840	3519	11	12	407	6555	7043	6381	17725	73	54	1.7
		09/10/76	2330		7.04	382	3969	12	12	316	7987	8366	5495	18173	38	54	5.0
		09/11/76	0730		7.04	216	3533	7	11	642	6714	7484	4786	15915	21	50	3.9
		09/11/76	1530		7.00	110	3319	8	11	1266	6250	7769	4520	15484	11	54	-3.6
		09/11/76	2330		6.75	70	3789	10	12	1560	6409	8281	4520	16370	6	52	5.1
		09/12/76	0730		7.11	76	4069	10	16	1899	6250	8529	4963	17283	6	50	6.4
		09/12/76	1530		6.37	79	3579	10	14	1764	6442	8559	4975	16763	7	54	-5.5
		09/12/76	2330		7.15	71	3829	9	15	1560	6921	8793	4697	17132	7	54	1.2
		09/13/76	0730		7.07	76	4020	9	16	1831	7834	10031	3994	17780	8		4.1
		09/13/76	1530		6.99	73	3730	9	15	1922	6978	9284	4981	17607	7		-6.3
		09/13/76	2330		6.99	68	3710	8	17	1673	7020	9028	4615	17111	7		-2.9
		09/14/76	0730		6.92	61	3740	7	16	1786	6258	8401	4438	16306	5		3.6
		09/14/76	1530		6.98	104	3320	8	15	1221	7136	8601	4093	15867	11		-5.4
	1821	09/09/76	1600	X													
		09/10/76	1530														
		09/11/76	1530														
		09/12/76	1530														
		09/13/76	1530														
		09/14/76	1530														
642-1A	1816	09/15/76	1600		6.80	165	3640	7	16	859	7933	8964	4525	17146	18		-1.9
		09/15/76	2330		7.13	593	3690	10	15	226	6914	7185	6035	17483	54		4.2
		09/16/76	0730		6.55	640	3610	12	18	384	7151	7612	5414	17229	61		5.7
		09/16/76	1530		6.96	191	3830	12	18	361	7998	8431	5680	18090	20		-3.1
		09/16/76	2330		6.98	325	3490	10	13	443	6931	7463	5503	16715	32		-2.1
		09/17/76	0730		7.03	630	3719	11	14	294	8112	8465	5424	18204	65	50	2.7
		09/17/76	1530		6.98	279	4229	11	15	520	8020	8644	5761	18835	27	54	5.6
		09/17/76	2330		7.05	192	3539	6	16	429	6969	7484	5140	16291	19	50	0.2
		09/18/76	0730		6.87	149	3969	7	16	927	6438	7550	5850	17356	13	53	3.7
		09/18/76	1530		7.00	179	3519	8	19	723	6004	6872	5672	16124	16	52	-1.3
		09/18/76	2330		7.07	253	4079	12	16	633	6482	7242	6204	17679	21	50	6.7
		09/19/76	0730		6.79	79	4459	11	16	1786	5965	8108	6027	18343	6	53	8.8

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
642-1A	1816	09/19/76	1530		6.95	102	4069	12	17	1402	7026	8708	6293	18921	9	52	-5.3
		09/19/76	2330		7.04	80	3669	12	15	1651	6505	8486	4963	16895	7	50	-3.2
		09/20/76	0730		7.10	96	4129	11	18	1537	8623	10467	5761	20175	10	54	-10.1
		09/20/76	1530		7.04	1178	4059	11	18	135	10348	10510	5496	21155	135	54	5.7
		09/20/76	2330		6.90	1000	4069	12	13	171	8366	8571	7030	20721	96	50	1.8
		09/21/76	0500		7.03	630	4269	12	16	316	9016	9395	7268	21527	65	50	-4.4
		09/22/76	1530		7.15	383	4199	12	17	429	7635	8150	6204	18879	35	54	5.7
		09/22/76	2330		6.86	459	4119	11	16	294	8527	8880	5672	19098	47	53	4.9
		09/23/76	0730		6.94	762	4359	10	15	271	10078	10403	6381	21875	84	52	0.2
		09/23/76	1530		7.06	842	4269	13	19	248	9204	9502	7622	22217	47	52	-4.7
		09/23/76	2330		7.08	331	4169	12	18	361	8618	9051	5850	19359	34	53	2.0
		09/24/76	0730	X	6.62	956	4369	10	15	160	10916	11132	6581	22627	111	52	-0.9
		09/24/76	1530		7.23	278	4379	13	18	497	8575	9171	5495	19255	28	50	7.8
		09/24/76	2330		6.95	539	4209	9	15	407	8692	9180	5672	19543	55	53	6.1
		09/25/76	0730		6.82	546	4309	12	17	361	10549	10982	6233	22087	65	54	-6.1
		09/25/76	1530		6.97	309	4089	13	17	588	8401	9107	5072	19089	32	50	0.9
		09/25/76	2330		7.00	444	3719	11	17	497	8305	8901	5436	19339	40	54	-2.7
		09/26/76	0730		7.04	681	4339	11	16	226	10196	10467	5761	21230	77	54	2.9
		09/26/76	1530		7.17	633	3869	13	18	226	9221	9492	5318	19238	71	50	0.9
		09/26/76	2330		7.07	622	3989	13	15	271	8576	8901	5052	18538	65	53	9.3
		09/27/76	0500		6.83	646	3979	14	18	248	9830	10188	5140	19235	75	53	1.0
	1821	09/15/76	1600														
		09/16/76	1530														
		09/17/76	1530														
		09/18/76	1530														
		09/19/76	1530														
		09/20/76	1530														
		09/22/76	1530														
		09/23/76	1530														
		09/24/76	1530														
		09/25/76	1530														
		09/26/76	1530														
	1825	04/01/75	0700		4.80	2090	163	50	159	760	880	1792	2942	7044	70	53	2.9
643-1A	1816	09/27/76	1530	X	7.34	661	3689	13	16	90	8784	8892	5140	18393	74	50	2.2
		09/27/76	2330		6.95	282	3379	13	17	474	7238	7807	4431	15834	30	54	1.9
		09/28/76	0730		7.12	122	4389	11	12	1198	9115	10553	4520	19367	13	53	5.6
		09/28/76	1530		6.59	160	3759	8	15	949	7325	8464	4786	17002	16	50	2.1
		09/28/76	2330		6.99	101	3809	13	18	949	6797	7936	4963	16650	9	54	4.5
		09/29/76	0730		6.75	110	4099	12	10	1176	7160	8571	4375	17442	10	53	8.0
		09/29/76	1530		7.06	128	3979	13	18	882	7384	8442	4263	17267	13	50	3.3
		09/29/76	2330		7.11	125	3289	12	18	995	6635	7829	4875	15949	13	54	-8.2
		09/30/76	0730		7.00	103	3579	12	19	1062	6319	7593	4786	15940	9	52	2.5
		09/30/76	2330		7.05	91	3519	12	17	1266	6288	7807	4520	15713	8	54	1.7
		10/01/76	0730		7.15	83	3549	14	20	1357	6501	8129	4254	15778	9	50	2.7
		10/01/76	1530		6.60	85	3469	12	19	1266	6181	7700	4743	15374	8	54	2.7

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
643-1A	1816	10/01/76	2330		6.93	79	3309	12	18	1311	6041	7614	3900	14670	7	54	3.1
		10/02/76	0730		6.79	76	3709	12	13	1289	7097	8644	3722	15918	8	52	8.0
		10/02/76	1530		7.05	79	3229	12	13	1470	5872	7636	3545	14220	7	53	4.2
		10/02/76	2330		7.00	113	3159	11	18	882	6256	7314	3811	14250	11	54	2.5
		10/03/76	0730		6.97	148	3729	12	15	814	6423	7400	4697	15838	13	54	9.1
		10/03/76	1530		6.94	133	4019	13	15	791	7437	8396	5495	17903	13	54	2.6
		10/03/76	2330		6.91	232	3959	10	17	588	7466	8172	6027	18299	22	54	-0.6
		10/04/76	0730		6.96	90	4329	16	18	1334	7290	8691	4875	17952	8	53	10.8
		10/04/76	1530		7.04	165	3879	21	19	836	7105	8108	5318	17343	16	52	3.0
		10/04/76	2330		7.04	99	3569	14	19	1176	6139	7550	4875	15891	9	54	1.7
		10/05/76	0730		7.04	80	3809	14	18	1357	4779	6407	5140	15197	5	50	12.6
	1821	10/01/76	1530														
		10/02/76	1530														
		10/03/76	1530														
		10/04/76	1530														

LIQUID ANALYSES

RUN NO.	ANALY TICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SUL-FATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
VFS-1A	1816	10/10/76	1730		6.96	240	333	7	11	22	1368	1394	531	2512	31	53	-10.1
		10/10/76	2330		6.45	117	3479	21	27	1515	6011	7829	4077	15247	10	52	5.7
		10/11/76	0730		6.94	280	2769	23	12	316	6163	6542	3722	13305	30	54	1.4
		10/11/76	1530		6.96	611	2389	22	13	407	6483	6971	4077	14602	61	54	6.3
		10/11/76	2330		6.99	764	3069	40	35	113	7899	8035	4502	16422	87	50	-0.3
		10/12/76	0730		7.04	229	3609	34	42	565	7279	7957	4165	15923	23	52	8.9
		10/12/76	1530		6.91	514	3289	32	36	384	7046	7537	4963	16264	52	54	0.8
		10/12/76	2330		7.07	149	3419	36	41	768	7164	8096	4431	16007	16	53	-0.7
		10/13/76	0730		7.04	76	2699	35	40	1221	6074	7539	3102	13277	8	54	-7.4
		10/13/76	1530		6.87	68	3349	34	39	1854	6227	8452	3368	14939	7	54	3.7
		10/13/76	2330		6.98	109	3689	34	31	1370	5739	7383	4077	15048	8	52	13.6
		10/14/76	0730		7.04	67	3859	37	49	1583	7869	9769	4254	17719	7	52	0.1
		10/14/76	1530		6.85	79	4089	35	22	1945	7563	9857	4443	18076	8	54	4.1
		10/14/76	2330		6.98	112	3279	36	52	904	6977	8062	3722	15062	12	52	1.9
		10/15/76	0730		7.07	238	3559	46	55	497	6922	7516	4343	15660	23	53	9.4
		10/15/76	1530		6.92	278	3599	46	54	497	6964	7560	4254	15692	27	53	11.5
		10/15/76	2330		6.95	302	3519	25	55	474	6899	7468	3900	15174	29	53	13.5
		10/16/76	0730		6.95	106	3429	29	52	372	5779	6945	4431	14798	9	52	7.0
		10/16/76	1530		7.04	109	3909	51	65	1221	7149	8614	4690	17134	10	50	5.9
		10/16/76	2330		7.03	78	3549	56	57	1537	6346	8190	4254	15877	7	50	3.1
		10/17/76	0730		7.02	81	3489	59	58	1447	6462	8198	4254	15850	8	50	1.5
		10/17/76	1530		6.98	88	3979	57	59	1854	7120	9345	4254	17411	8	53	6.3
		10/17/76	2330		7.04	82	3739	42	27	1492	6550	8232	3900	15712	8	50	9.7
	1821	10/11/76	1530														
		10/12/76	1530														
		10/13/76	1530														
		10/14/76	1530														
		10/15/76	1530														
		10/16/76	1530														
		10/17/76	1530														
VFS-1B	1816	10/21/76	0730		7.79	606	170	8	12	45	1347	1401	354	2542	70	54	12.8
		10/21/76	1530		7.79	608	163	9	11	203	1242	1486	265	2501	67	52	13.5
		10/21/76	2330		7.96	714	216	14	8	22	1609	1635	443	3026	82	52	14.2
		10/22/76	0730		7.94	832	210	13	10	90	2228	2336	476	3929	119	54	-0.8
		10/22/76	1530		8.00	730	224	12	28	45	2195	2249	531	3765	106	52	-10.2
		10/22/76	2330		8.17	788	221	14	30	90	1930	2038	620	3693	100	52	-1.8
		10/23/76	0730		8.04	736	250	15	30	90	1867	1975	531	3519	91	54	4.5
		10/23/76	1530		8.04	796	273	12	9	22	1989	2015	896	3987	97	53	-6.4
		10/23/76	2330		8.03	830	302	14	29	45	1581	1635	485	3587	79	52	12.7
		10/24/76	0730		8.21	1138	296	14	31	36	2187	2230	886	4588	121	54	13.5
		10/24/76	1530		8.16	1298	308	13	10	135	2065	2227	1418	5247	120	52	5.0
		10/24/76	2330		8.04	1396	302	12	12	90	1867	1975	1506	5185	114	52	12.3
		10/25/76	0730		7.95	948	350	13	32	45	1687	1741	1453	4528	85	54	0.3

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
VFG-1B	1816	10/25/76	1530		8.14	796	377	13	11	0	1654	1654	1240	4091	75	50	3.0
		10/25/76	2330		7.99	748	419	14	11	90	1166	1274	1329	3777	51	52	11.9
		10/26/76	0730		7.79	742	388	14	15	113	1296	1422	1329	3867	57	52	4.1
		10/26/76	1530		7.96	810	410	13	14	38	1394	1440	1420	4099	63		6.7
					7.96	725	376	13	14	38	1540	1586	1420	4126	67		-7.4
		10/26/76	2330		7.92	2150	531	14	16	49	1727	1785	3816	8302	105		4.7
		10/27/76	0730		7.98	1865	426	14	92	11	1473	1486	3126	5987	94		9.6
		10/27/76	1530		8.16	2570	417	13	83	48	1671	1729	3728	8530	118		14.6
		10/27/76	2330		7.96	2035	402	6	48	24	1653	1682	3817	7965	109		-4.6
		10/28/76	0730		7.85	2255	462	15	75	88	1748	1854	3639	8282	115	50	7.9
		10/28/76	1530		8.03	2250	595	15	72	48	2084	2142	4526	9580	128	50	-5.7
		10/28/76	2330		7.85	2180	508	14	68	45	1723	1777	3916	8354	110	54	5.4
		10/29/76	0730		8.02	2310	569	6	82	67	1914	1994	3829	8777	120	50	9.1
	1821	10/22/76	1530														
		10/23/76	1530														
		10/24/76	1530														
		10/25/76	1530														
VFG-1C	1816	10/29/76	1530		8.17	2115	493	12	85	90	1676	1794	3900	8371	107	51	1.1
		10/29/76	2330		7.93	2135	508	13	58	361	1266	1699	4431	8772	82	54	-5.6
		10/30/76	0730		7.99	2080	529	13	75	90	1527	1635	3811	8125	96	51	5.5
		10/30/76	1530		8.00	2020	556	13	77	45	1390	1444	4165	8266	85	51	1.0
		10/30/76	2330		8.03	2475	600	14	75	90	1803	1911	4609	9666	115	54	3.2
		10/31/76	2330		7.90	2290	535	12	73	45	1730	1784	4609	9294	111	54	-4.0
		11/01/76	0730		8.04	2020	553	32	96	113	892	1018	3900	7656	56	50	14.3
		11/01/76	1530		8.04	2380	610	35	95	90	1676	1784	4254	9140	106	51	9.1
		11/01/76	2330		7.95	2260	558	36	96	45	1241	1295	5229	9465	80	50	-7.2
		11/02/76	0730		8.11	2290	581	28	60	90	1207	1315	4077	8333	77	50	13.6
		11/02/76	1530		7.86	2270	697	30	59	90	1208	1316	4609	8963	73	52	9.2
	1825	11/01/76	1530		4.95	3280	619	32	102	768	1923	2845	4520	11244	134	51	14.6
		11/01/76	2330		4.75	2780	683	34	97	949	1367	2506	4431	10341	93	46	10.9
		11/02/76	0730		4.73	2510	578	27	73	972	1295	2461	4254	9799	85	51	2.6
		11/02/76	1530		4.62	2619	687	29	77	542	2111	2761	4697	10762	132	53	0.3
VFG-1D	1816	11/02/76	2330		7.90	2130	574	30	56	180	1037	1253	3988	7955	65	52	11.3
		11/03/76	0730		7.91	2340	569	36	96	22	1460	1486	4254	8777	94	52	10.0
		11/03/76	1530		7.94	1755	463	34	100	22	1168	1194	4165	7707	72	52	-9.7
		11/03/76	2330		8.08	1640	600	40	103	45	927	981	4431	7786	52	50	-7.2
		11/04/76	0730		7.95	1660	596	34	86	135	607	769	3722	6940	35	50	10.7
		11/04/76	1530		7.87	1855	572	32	84	22	743	769	4077	7385	45	51	0.5
		11/04/76	2330		7.91	1645	577	33	80	90	741	849	3998	7154	43	50	2.2
		11/05/76	0730		7.73	1475	594	37	96	13	540	555	3811	6566	30	48	5.9
		11/05/76	1530		8.04	1510	597	36	99	45	285	339	3722	6284	16	50	12.3
		11/05/76	2330		8.02	1430	586	148	94	45	370	424	3651	6324	20	50	12.9
		11/06/76	0730		8.08	1225	571	31	83	22	530	556	3545	6007	27	53	0.0
		11/06/76	1530		7.89	1490	578	34	92	67	238	313	3722	6211	13	50	10.9
	1825	11/02/76	2330		4.29	2230	581	32	76	723	1213	2081	3930	8755	77	52	5.6

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
VFG-1D	1825	11/03/76	0730		4.91	2200	549	36	94	565	1743	2421	4343	9530	109	52	-8.8
		11/03/76	1530		5.11	1825	466	32	98	271	1320	1645	3998	8000	82	52	-10.1
		11/03/76	2330		4.87	1570	602	37	96	180	844	1060	4077	7406	47	50	-3.9
		11/04/76	0730		5.31	1590	588	33	84	158	817	1057	3900	7170	46	50	0.3
		11/04/76	1530		5.06	1925	614	35	85	316	815	1194	4165	7955	49	51	5.3
		11/04/76	2330		5.20	1655	579	34	88	226	658	929	3998	7228	38	50	1.6
		11/05/76	0730		5.43	1500	603	35	91	45	423	477	3920	6527	23	48	6.5
		11/05/76	1530		5.54	1655	602	35	93	225	164	435	3900	6675	10	48	12.5
		11/05/76	2330		5.50	1370	587	166	99	45	392	446	3722	6381	21	50	9.6
		11/06/76	0730		5.43	1260	568	34	102	90	502	610	3634	6190	26	53	-1.3
		11/06/76	1530		5.58	1510	572	33	98	135	262	424	3900	6510	15	49	6.0
VFG-1E	1816	11/06/76	2330		7.33	1420	564	36	87	113	394	530	3368	5982	22	51	12.4
		11/07/76	0730		7.83	1760	647	35	82	22	1326	1352	3545	7417	74	52	11.4
		11/07/76	1530		7.83	1630	592	26	101	67	1258	1338	3722	7398	70	48	0.8
		11/07/76	2330		7.95	1610	597	37	103	45	1114	1166	3545	7051	62	50	7.0
		11/08/76	0730		8.15	1510	665	36	100	90	805	913	3368	6574	42	50	15.0
		11/08/76	1530		8.10	1570	525	34	99	113	713	849	3279	6333	42	48	12.3
		11/08/76	2330		8.15	1270	490	34	96	113	352	488	3102	5367	21	51	2.6
		11/09/76	0730		8.07	1505	468	39	115	45	476	530	3130	5838	29	51	14.6
		11/09/76	1530		8.16	1705	540	40	96	90	826	934	3368	6655	49	49	14.4
		11/09/76	2330		8.06	1675	444	45	108	22	637	663	3545	6476	40	52	9.6
		11/10/76	0730		8.02	2060	493	44	106	113	426	562	4343	7585	28	51	9.3
		11/10/76	1530		8.07	1930	442	40	107	135	422	584	4077	7153	28	50	7.3
	1825	11/06/76	2330		5.20	1530	573	36	87	294	369	722	3456	6345	21	52	11.6
		11/07/76	0730		4.31	2020	651	34	79	1108	1507	2637	3722	9121	88	52	-3.9
		11/07/76	1530		4.29	2070	617	30	105	1289	1468	3015	3456	9036	88	52	-1.4
		11/07/76	2330		4.91	1675	593	36	99	927	1203	2315	2836	7369	69	50	6.1
		11/08/76	0730		4.83	1790	605	35	99	723	1096	1964	3368	7806	60	50	9.7
		11/08/76	1530		5.16	1610	618	35	101	565	660	1338	3545	7134	37	50	5.5
		11/08/76	2330		5.08	1330	486	35	97	407	616	1104	3279	6250	35	52	-4.6
		11/09/76	0730		5.00	1540	549	40	115	585	547	1253	3279	6662	32	51	6.5
		11/09/76	1530		4.69	1690	508	39	98	610	960	1592	3456	7261	52	50	-0.2
		11/09/76	2330		4.75	1750	472	43	108	407	1235	1723	3722	7737	76	52	-7.7
		11/10/76	0730		4.90	2230	510	43	104	610	744	1476	4343	8584	55	51	2.9
		11/10/76	1530		4.86	2090	467	39	111	814	629	1606	4165	8315	42	50	-2.5
VFG-1F	1816	11/10/76	2330		7.96	2210	461	45	100	113	649	785	4254	7832	45	52	10.7
		11/11/76	0730		7.87	2220	540	44	102	22	975	1001	4343	8246	54	51	10.3
		11/11/76	1530		8.00	1955	525	44	120	45	822	876	4343	7854	52	50	3.4
		11/11/76	2330		7.99	2020	505	57	10	45	1145	1199	4077	7859	73	52	3.5
		11/12/76	0730		7.96	2210	527	56	113	45	1697	1751	4077	8725	108	52	4.7
		11/12/76	1530		7.95	2130	531	57	115	45	1135	1189	3900	7913	73	50	13.3
		11/12/76	2330		7.83	2200	530	65	108	45	1155	1209	4254	8357	75	52	8.7
		11/13/76	0730		7.83	2180	582	67	107	45	1020	1074	4165	8166	65	50	13.3
		11/15/76	1530		7.82	2140	634	62	138	67	2150	2230	3900	9091	126	50	5.3
		11/15/76	2330		7.91	2549	591	62	138	0	1188	1138	5672	10200	79	51	-1.5

LIQUID ANALYSES

RUN NO.	ANALY TICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SUL-FATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
VFG-1F	1816	11/15/76			7.91	2549	591	62	138	0	1188	1188	3816	9344	79	51	27.3
		11/16/76	0730		7.93	2440	427	63	121	45	1532	1586	4254	9288	106	50	6.1
		11/16/76	1530		8.00	1895	545	70	121	135	860	1032	3722	7348	53	52	13.2
		11/16/76	2330		7.87	2340	572	69	120	45	1218	1272	4077	8141	75	49	8.7
		11/17/76	0730		7.95	1850	511	78	127	135	881	1043	4165	7747	55	50	1.3
		11/17/76	1530		7.99	2270	560	63	128	113	685	1021	4254	8273	59	51	14.6
		11/17/76	2330		7.99	2090	554	64	122	90	799	997	4254	7963	50	51	11.3
		11/18/76	0730		7.99	2800	563	68	122	226	1294	1565	5140	10223	89	50	7.7
	1825	11/10/76	2330		4.48	2370	457	47	105	1239	956	2503	4077	9331	65	52	-2.5
		11/11/76	0730		4.68	2370	536	44	100	1221	1283	2754	3900	9460	85	34	-0.3
		11/11/76	1530		4.66	2370	571	43	119	1221	1267	2732	4431	10022	82	49	-6.9
		11/11/76	2330		4.79	2450	532	59	119	814	586	1563	4077	8637	40	52	14.0
		11/12/76	0730		4.41	2450	511	61	119	1379	1493	3148	4077	10089	100	52	-6.2
		11/12/76	1530		4.62	2500	557	62	117	1130	1607	2963	4254	10227	106	51	-3.1
		11/12/76	2330		4.35	2669	557	58	97	1334	1339	2939	4431	10484	91	52	-1.0
		11/13/76	0730		4.40	2950	683	56	94	904	1899	2984	4077	10663	125	50	14.9
		11/15/76	1530		4.53	2559	691	76	135	1447	1673	3409	3722	10303	105	50	8.0
		11/15/76	2330		4.49	2619	563	75	136	0	1501	1501	5319	10212	100	51	1.4
					4.49	2619	563	75	136	0	1501	1501	4092	8976	100	51	20.3
		11/16/76	0730		4.61	2190	566	72	125	1176	1301	2712	4077	9509	92	50	-5.6
		11/16/76	1530		4.62	2090	550	73	125	1198	1191	2629	3811	9038	75	53	-4.0
		11/16/76	2330		4.57	2420	580	70	121	1017	1492	2712	4165	9865	95	48	0.4
		11/17/76	0730		4.34	2370	581	75	132	1221	1268	2733	4254	9901	92	48	-2.4
		11/17/76	1530		4.69	2460	561	67	128	1311	1116	2689	4149	9731	74	50	1.2
		11/17/76	2330		4.77	2240	536	66	125	1062	1105	2379	4077	9211	72	49	-1.6
		11/18/76	0730		4.75	3540	681	65	128	1085	1870	3172	5406	12775	131	49	8.5
VFG-1G	1816	11/18/76	1730		7.99	2520	549	62	127	203	611	855	4697	8769	42	51	15.0
		11/18/76	2330		7.96	2650	627	63	126	113	281	417	5672	9532	13	50	11.1
		11/19/76	0800		7.77	2080	573	68	114	180	201	417	5052	8268	13	50	3.6
		11/19/76	1530		7.83	2240	578	60	109	90	475	563	4786	8338	31	52	10.7
		11/19/76	2330		8.29	2530	672	57	113	45	1010	1064	4963	9390	65	50	13.3
		11/20/76	0730		7.95	2180	654	70	122	180	660	876	4520	8386	41	50	13.6
		11/20/76	1530		8.29	2140	659	57	113	45	675	729	4609	8298	42	54	12.7
		11/20/76	2330		7.90	2050	695	59	110	135	777	939	4609	8435	46	52	9.3
		11/21/76	0730		7.73	2120	737	63	113	180	931	1147	4343	8427	54	50	14.9
	1825	11/18/76	1730		5.45	2569	569	65	122	248	766	1064	5140	9479	52	51	7.6
		11/18/76	2330		5.28	2530	617	64	124	180	263	479	5229	9007	18	50	13.9
		11/19/76	0800		5.08	2240	608	70	121	271	447	772	5052	8809	23	49	5.6
		11/19/76	1530		4.92	2410	611	68	119	497	321	1417	4609	9155	54	52	9.6
		11/19/76	2330		4.87	2669	682	57	123	723	1385	2253	4786	10425	89	50	6.7
		11/20/76	0730		4.90	2490	679	74	118	859	1201	2232	4520	9941	76	47	6.7
		11/20/76	1530		4.99	2050	621	58	109	701	925	1667	4520	8885	51	54	-2.2
		11/20/76	2330		5.00	2280	717	61	111	1040	943	2191	4375	10027	57	53	-2.7
		11/21/76	0730		4.81	2470	790	66	110	904	1252	2337	4254	9876	76	48	12.7
VFG-1I	1816	11/22/76	1700		7.93	2110	635	60	124	45	794	848	4431	8199	45	50	12.7

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
VFG-1I	1816	11/22/76	2330		8.17	1860	728	45	125	90	476	584	4343	7667	27	50	14.7
		11/23/76	0730		7.86	1790	707	42	120	90	475	583	4343	7567	27	50	11.6
		11/23/76	1530		7.91	1850	747	66	129	45	759	813	4786	8392	42	53	5.0
		11/23/76	2330		7.96	1980	663	69	133	90	914	1022	4786	8635	54	50	2.2
		11/24/76	0730		7.99	2070	683	65	125	22	1204	1230	4736	8955	71	50	3.0
		11/24/76	1530		8.25	1945	687	49	116	45	988	1042	4609	8439	57	53	4.4
		11/24/76	2330		7.91	1685	653	46	126	45	780	834	4254	7589	43	50	4.0
		11/25/76	0730		8.06	1720	717	43	123	113	719	855	3998	7423	39	52	13.0
		11/25/76	1530		8.00	1670	683	59	111	45	738	792	4077	7383	40	53	9.3
		11/25/76	2330		8.04	1535	717	67	112	45	634	688	3811	6921	33	50	13.8
		11/26/76	0730		7.96	1480	745	71	113	22	661	687	3900	6992	33	50	11.0
		11/26/76	1530		7.94	1380	779	70	102	22	558	584	3900	6811	27	50	11.9
		11/26/76	2330		7.99	1285	703	74	98	22	516	542	3900	6598	25	49	5.0
		11/27/76	0730		7.90	1260	739	66	96	45	571	625	3811	6588	27	50	5.6
	1825	11/22/76	1700		5.12	2030	625	60	125	226	789	1060	4290	8145	48	50	9.7
		11/22/76	2330		4.94	1880	756	47	128	497	614	1210	4431	8353	34	49	6.9
		11/23/76	0730		4.77	1890	777	39	123	678	895	1709	4431	8833	49	49	1.5
		11/23/76	1530		5.03	1925	775	64	126	429	881	1396	4431	8631	49	53	7.1
		11/23/76	2330		4.91	2085	677	68	130	226	1607	1878	4875	9668	93	49	-6.4
		11/24/76	0730		4.79	2120	701	65	125	294	1585	1938	4520	9410	92	50	1.0
		11/24/76	1530		4.98	2005	707	48	113	497	1134	1730	3900	8404	65	53	10.5
		11/24/76	2330		4.79	1775	671	48	129	768	1039	1961	3900	8330	58	48	-1.1
		11/25/76	0730		4.95	1725	701	45	123	610	833	1565	3634	7671	45	53	9.3
		11/25/76	1530		4.86	1880	741	61	115	542	1080	1730	4254	8673	59	53	2.7
		11/25/76	2330		4.70	1720	727	71	116	678	897	1711	4077	8286	48	49	0.7
		11/26/76	0830		4.77	1485	747	71	114	316	1330	1709	3793	7856	65	50	-0.7
		11/26/76	1530		4.70	1490	735	70	103	814	734	1711	3811	7747	37	50	-2.2
		11/26/76	2330		4.53	1460	725	68	102	723	1051	1919	3811	7940	52	46	-6.8
		11/27/76	0730		4.53	1415	717	67	100	655	1298	2084	3900	8152	53	52	-13.6
VFG-1F	1816	11/27/76	1530		7.91	1485	731	66	96	135	902	1064	3722	7137	45	51	8.9
		11/27/76	2330		7.81	1430	573	63	97	45	780	834	3368	6356	42	49	9.2
		11/28/76	0730		7.95	1350	529	57	92	45	925	979	3013	6011	50	50	8.9
		11/28/76	1530		8.14	1840	647	56	90	67	1224	1304	3900	7824	70	46	8.4
		11/28/76	2330		7.82	1825	657	58	93	90	1248	1356	3988	7959	70	50	5.2
		11/29/76	0730		7.91	1515	695	55	88	90	1018	1126	3900	7361	52	50	2.9
		11/29/76	1530		8.00	1620	673	55	93	67	1067	1147	4077	7652	57	51	1.5
		11/29/76	2330		8.00	1610	619	40	98	22	1246	1272	4077	7712	68	50	-4.4
		11/30/76	0730		8.00	1440	1065	52	103	90	1622	1730	3722	8094	65	53	14.2
					8.00	1440	573	52	103	90	1622	1730	3722	7562	87	53	-16.9
		11/30/76	1530		7.85	1530	725	50	94	67	723	803	3722	6911	37	47	13.4
		11/30/76	2330		8.04	1575	695	52	106	22	933	959	3651	7034	49	50	12.6
		12/01/76	0730		8.04	1450	623	50	103	22	1120	1146	3545	6913	58	53	3.6
		12/01/76	1530		7.49	1625	715	48	105	113	1272	1408	3545	7423	66	51	10.6
		12/01/76	2330		8.11	1515	741	50	104	135	912	1074	3545	7002	46	52	13.5
		12/02/76	0730		7.98	1460	723	46	93	90	892	1000	3545	6849	44	53	11.6

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
VFG-1P	1816	12/02/76	1530		7.94	1635	749	49	95	113	1272	1408	3811	7724	65	50	7.4
		12/02/76	2330		7.87	1720	735	51	96	22	1268	1294	3793	7695	57	50	11.3
		12/03/76	0730		7.98	1590	715	48	91	22	1162	1188	3722	7350	60	53	9.0
		12/03/76	1530		7.83	1540	715	48	88	45	1177	1231	3988	7601	60	50	1.4
		12/03/76	2330		8.11	1565	753	49	90	45	885	939	3988	7375	45	52	8.6
	1825	11/27/76	1530		4.73	1800	769	64	102	1130	1461	2817	3811	9137	77	51	-4.9
		11/27/76	2330		4.78	1595	595	58	95	949	1135	2274	3456	7583	53	46	-8.5
		11/28/76	0730		4.50	1685	545	60	96	1130	728	2084	3079	7517	43	50	-1.5
		11/28/76	1530		4.55	2145	651	59	88	882	1675	2733	3722	9222	99	48	2.1
		11/28/76	2330		4.91	2005	663	61	91	904	1649	2733	4077	9449	95	47	-7.7
		11/29/76	0730		4.66	1570	665	58	95	814	1422	2399	3722	8346	74	50	-12.3
		11/29/76	1530		4.45	1915	699	60	98	859	1494	2525	4343	9465	83	51	-10.7
		11/29/76	2330		4.93	1715	631	42	100	768	1665	2587	4165	9286	95	47	-12.8
		11/30/76	0730		4.62	1580	1047	51	94	859	1825	2854	3190	8646	75	53	11.9
					4.62	1580	597	51	94	859	1825	2856	3190	8126	101	53	-17.8
		11/30/76	1530		4.87	1800	723	52	103	949	999	2128	3722	8336	54	49	3.2
		11/30/76	2330		4.79	1745	702	51	105	316	1997	2376	3545	8461	104	50	0.2
		12/01/76	0730		4.81	1705	604	47	96	1085	1470	2772	3634	8641	82	53	-15.0
		12/01/76	1530		4.68	1880	749	50	98	1040	1830	3078	3900	9547	97	51	-8.7
		12/01/76	2330		4.78	1775	747	52	102	904	1523	2608	3900	9003	60	53	-6.1
		12/02/76	0730		4.66	1685	759	48	99	1334	1213	2814	3545	8303	63	53	-4.9
		12/02/76	1530		4.77	1855	743	49	101	1379	974	2629	3811	8912	54	50	-2.4
		12/02/76	2330		4.58	2035	731	49	99	814	1976	2953	3545	9249	109	50	2.9
		12/03/76	0730		4.66	1830	727	48	89	768	2017	2939	3900	9379	106	53	-10.1
		12/03/76	1530		4.62	1930	723	50	89	1085	1431	2733	4077	9385	79	45	-7.3
		12/03/76	2330		4.70	1850	787	54	90	995	1581	2775	4077	9434	83	54	-6.8
	2825	11/29/76	0700														
		11/30/76	0700														

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
629-1A	1816	04/29/76	2330	X	22.10	17.90	8.23	30.60	0.71	10.2	5.08	5.21	26.9	1.03	1.04	-1.1
		04/29/76	0730		26.40	22.30	8.73	36.60	0.25	10.4	4.27	4.40	23.9	1.03	1.01	1.7
		04/29/76	1530		27.00	24.60	7.75	38.50	0.30	9.4	3.73	3.79	20.1	1.00	1.01	-1.3
		04/29/76	2330		30.00	24.80	14.10	45.10	0.44	13.3	3.69	4.08	31.3	0.95	1.02	-7.2
		04/30/76	0730		27.10	25.90	8.33	40.70	0.55	8.3	3.11	3.16	20.5	0.95	1.02	-7.8
		04/30/76	1530		29.50	26.50	10.28	43.90	0.64	8.1	2.56	2.65	23.4	0.96	1.03	-7.0
		04/30/76	2330		27.90	25.30	9.88	41.50	0.44	8.4	2.97	3.06	23.8	0.96	1.02	-6.2
		05/01/76	0730		28.10	26.10	9.58	42.20	0.19	9.3	3.26	3.35	22.7	0.95	1.01	-6.1
		05/03/76	2330		29.00	27.20	8.71	42.70	0.22	9.5	3.26	3.31	20.4	0.97	1.01	-4.1
		05/04/76	0730		27.00	23.30	8.28	37.40	0.27	9.7	3.91	3.99	22.1	1.03	1.01	1.7
		05/04/76	1530		28.90	27.20	7.11	41.10	0.37	8.5	3.10	3.11	17.3	1.00	1.02	-1.5
		05/04/76	2330		28.30	23.00	11.95	41.70	0.71	8.5	2.81	3.00	28.7	0.97	1.03	-6.4
		05/05/76	0730		29.30	27.30	8.58	42.70	0.11	10.1	3.46	3.51	20.1	0.98	1.00	-2.6
		05/05/76	1530		24.40	20.80	9.50	35.50	0.83	9.9	4.23	4.40	26.8	0.98	1.04	-5.2

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
629-1A	1816	05/05/76	2330		26.50	23.50	9.23	38.60	0.33	8.5	3.32	3.44	23.9	0.98	1.02	-3.6
		05/06/76	0730		23.70	20.70	5.43	31.30	1.26	8.5	4.20	4.16	17.3	1.08	1.07	0.7
		05/06/76	1530		23.30	23.60	3.40	32.90	0.61	8.6	4.21	4.22	10.3	1.01	1.03	-2.2
		05/06/76	2330		23.50	21.80	5.65	32.90	0.52	9.3	4.53	4.51	17.2	1.02	1.03	-0.9
		05/07/76	0730		24.20	20.50	8.58	34.20	0.25	8.8	3.93	4.09	25.1	1.01	1.01	-0.3
		05/07/76	1530		23.60	23.30	3.53	32.70	0.33	8.7	4.41	4.28	10.9	1.03	1.02	1.2
		05/08/76	0730		28.30	26.70	7.43	40.80	0.19	8.3	3.12	3.10	13.2	0.99	1.01	-1.8
		05/08/76	1530		28.10	26.70	8.43	41.80	0.33	8.0	2.90	2.92	20.2	0.96	1.01	-5.7
		05/08/76	2330		24.90	23.50	6.40	35.90	0.87	7.7	3.43	3.41	17.8	0.99	1.04	-5.4
		05/09/76	0730		23.40	19.00	7.15	30.90	0.85	9.0	4.45	4.46	23.2	1.08	1.05	2.9
		05/09/76	1530		24.40	21.40	7.05	33.80	0.71	6.9	3.16	3.20	20.9	1.03	1.04	-0.7
		05/09/76	2330		24.60	23.50	5.43	34.80	0.21	8.3	3.45	3.34	15.6	1.01	1.01	-0.2
		05/10/76	0730		24.40	21.40	7.45	34.20	0.46	9.5	4.37	4.40	21.8	1.02	1.02	-0.6
		05/10/76	1530	X	23.00	24.30	0.33	30.70	0.77	7.2	0.65	3.72	1.1	1.07	1.05	2.2
		05/10/76	2330		27.50	24.10	8.78	38.90	0.66	8.0	3.03	3.12	22.6	1.01	1.03	-0.1
		05/11/76	0730		24.30	21.70	8.68	35.80	0.30	9.7	3.82	3.92	24.2	0.97	1.02	-4.6
		05/11/76	1530		23.70	20.00	8.20	33.20	0.27	8.2	3.84	3.92	24.7	1.02	1.01	0.4
		05/11/76	2330		24.80	18.00	10.00	32.50	0.38	7.2	3.22	3.37	30.8	1.09	1.02	6.3
		05/12/76	0730		23.00	21.40	5.75	32.50	0.20	10.3	5.12	5.11	17.7	1.01	1.01	-0.1
	1818	05/07/76	0730		25.00	22.40	8.10	36.10	0.19	28.6	12.47	12.67	22.5	0.99	1.01	-2.1
		05/10/76	0730		25.40	23.20	7.60	36.60	0.27	29.8	12.81	12.97	20.8	0.99	1.01	-2.3
	1821	04/30/76	1530		26.40	24.80	7.50	38.50	0.40	52.3		21.39	19.5	0.98	1.02	-4.1
		05/07/76	1530		25.40	21.50	9.03	35.90	0.05	58.0	24.74	25.53	25.2	1.01	1.00	0.7
		05/10/76	1530		23.10	22.10	4.68	32.30	0.99	57.1	31.74	28.06	14.5	1.02	1.06	-3.4
630-1A	1816	05/12/76	1530		25.90	27.80	3.76	38.50	0.77	9.4	4.09	3.93	9.8	0.96	1.04	-7.9
		05/12/76	2330		26.60	25.90	5.63	38.00	0.93	8.9	3.74	3.64	14.8	1.00	1.04	-4.5
		05/13/76	0730		25.00	23.20	6.00	35.00	0.64	7.4	3.37	3.34	17.2	1.02	1.03	-1.3
		05/13/76	1530		22.50	20.40	3.70	29.20	1.10	8.4	4.47	4.39	12.7	1.10	1.07	2.9
		05/13/76	2330		25.90	22.80	6.10	34.60	1.04	8.0	3.52	3.53	17.6	1.07	1.05	1.3
		05/14/76	0730		26.20	23.50	5.63	35.00	0.51	8.1	3.62	3.58	16.1	1.07	1.03	3.9
		05/14/76	1530		25.30	23.70	4.78	34.40	0.43	9.2	3.83	3.76	13.9	1.05	1.02	2.6
		05/14/76	2330		26.10	24.40	5.30	35.60	0.68	8.4	3.67	3.64	14.8	1.04	1.04	-0.4
		05/15/76	0730		24.30	22.50	6.18	34.30	0.55	8.6	3.99	4.00	18.0	1.01	1.03	-1.8
		05/15/76	1530		24.50	24.90	3.18	34.30	0.60	9.2	4.45	4.31	9.3	1.02	1.03	-1.2
		05/15/76	2330		25.90	22.60	6.65	34.90	1.04	9.7	4.26	4.25	19.1	1.06	1.05	0.5
		05/16/76	0730		27.50	25.50	7.83	39.70	0.56	9.1	3.49	3.51	19.7	0.99	1.03	-3.7
		05/16/76	1530		25.00	23.40	4.75	34.00	0.65	8.6	4.04	3.97	14.0	1.05	1.03	1.4
		05/16/76	2330		22.80	19.40	6.45	30.70	0.77	8.7	4.39	4.40	21.0	1.06	1.05	1.4
		05/17/76	0730		27.90	26.20	9.16	41.90	0.70	8.6	3.00	3.10	21.9	0.95	1.03	-8.4
		05/17/76	1530		25.70	25.40	6.06	37.80	0.70	8.1	3.46	3.41	16.0	0.97	1.03	-5.5
		05/17/76	2330		27.10	25.20	5.71	37.20	0.77	8.7	3.63	3.59	15.3	1.04	1.04	0.2
		05/18/76	0730		29.30	31.10	3.83	42.70	0.49	8.7	3.27	3.07	9.0	0.98	1.02	-4.2
	1818	05/14/76	0730	SO2	26.30	14.00	19.70	37.20	0.33	25.1	8.22	9.96	53.0	1.01	1.02	-0.7
		05/17/76	0730		27.00	26.40	7.61	40.60	0.60	25.9	9.92	9.95	18.7	0.95	1.03	-3.2
	1821	05/14/76	1530		24.90	22.90	5.58	34.20	0.38	49.7		22.99	16.3	1.04	1.02	1.8

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXICATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
630-1A	1821	05/17/76	1530		26.60	24.70	8.23	39.10	0.77				21.0	0.97	1.04	-5.7
631-1A	1816	05/18/76	1530		24.80	22.00	6.50	34.00	0.88	5.6	2.56	2.57	19.1	1.04	1.05	-0.6
		05/18/76	2330		23.80	20.40	7.20	32.70	0.68	9.7	4.60	4.65	22.0	1.04	1.04	0.1
		05/19/76	0730		21.80	18.90	6.88	30.50	0.38	7.3	3.75	3.80	22.6	1.02	1.02	-0.2
		05/19/76	1530		20.80	19.20	4.00	28.00	1.21	8.1	4.47	4.44	14.3	1.06	1.08	-1.7
		05/19/76	2330		22.10	17.90	7.63	30.00	0.53	7.1	3.61	3.63	25.4	1.05	1.03	1.9
		05/20/76	0730		24.70	22.90	5.58	34.20	0.27	9.5	4.51	4.47	16.3	1.03	1.01	1.6
		05/20/76	1600		20.00	20.50	2.08	27.70	0.71	8.6	5.01	4.98	7.5	1.03	1.05	-1.5
		05/20/76	2330		26.60	26.30	7.53	40.40	0.56	9.7	3.79	3.78	18.6	0.94	1.03	-9.1
		05/21/76	0730		27.60	26.90	6.58	40.20	0.44	9.0	3.51	3.46	16.4	0.98	1.02	-4.1
		05/21/76	1530		21.30	18.20	5.65	28.40	0.48	9.7	5.23	5.27	19.9	1.07	1.03	7.7
		05/21/76	2330		26.20	23.40	5.15	37.40	0.38	8.7	3.58	3.64	21.8	1.00	1.02	-1.8
		05/22/76	0730		23.10	20.90	5.58	31.70	0.60	8.4	4.17	4.19	17.6	1.04	1.03	0.6
		05/22/76	1530		26.60	23.60	5.00	34.50	0.30	8.6	3.89	3.82	14.5	1.10	1.02	7.3
		05/22/76	2330		23.90	20.70	6.63	32.50	0.53	8.2	3.93	3.96	20.4	1.05	1.03	1.9
		05/23/76	0730		23.00	15.90	9.93	29.80	0.71	8.5	4.05	4.29	33.3	1.10	1.04	5.3
		05/23/76	1530		26.80	24.40	7.00	37.50	0.49	9.3	3.94	3.94	18.7	1.02	1.02	-0.3
		05/23/76	2330		29.50	25.60	8.91	40.90	1.11	7.8	2.65	2.72	21.8	1.03	1.05	-1.9
		05/24/76	0730		22.60	21.30	3.28	29.90	0.99	7.8	4.17	4.04	11.6	1.08	1.06	1.7
	1821	05/21/76	1530		23.50	21.30	5.98	32.60	0.42	55.2		26.94	18.3	1.03	1.02	0.6
		05/24/76	0730		23.90	21.10	6.13	32.50	0.66				18.9	1.05	1.04	1.2
632-1A	1816	05/28/76	2330	X	22.80	22.10	4.88	32.50	0.49	10.0	5.00	4.97	15.0	1.00	1.03	-2.6
		05/29/76	0730	X	23.10	21.00	9.95	36.20	0.60	10.3	4.47	4.67	27.5	0.91	1.03	-12.1
		05/29/76	1530		27.30	24.70	11.93	42.80	0.35	8.6	2.88	3.07	27.3	0.91	1.01	-11.5
		05/29/76	2330		24.60	23.90	10.03	39.90	0.55	8.3	3.26	3.40	25.1	0.99	1.03	-10.5
		05/30/76	0730		24.00	23.90	7.33	37.20	0.54	9.0	3.96	3.99	19.7	0.92	1.03	-11.4
		05/30/76	1530		21.90	22.10	3.38	31.00	0.37	9.3	4.47	4.34	10.9	1.01	1.02	-1.3
		05/30/76	2330		23.40	22.60	3.85	32.10	0.49	8.0	4.04	3.97	12.0	1.04	1.03	1.2
		05/31/76	0730		23.50	22.50	3.28	31.40	0.49	8.0	4.12	4.02	10.4	1.07	1.03	3.7
		05/31/76	1530		26.70	23.80	9.95	39.70	0.48	7.5	2.89	2.93	25.1	0.96	1.02	-6.4
		05/31/76	2330		22.40	21.10	5.93	32.30	0.44	7.8	3.92	3.91	18.4	0.99	1.02	-3.5
		06/01/76	0730		21.70	20.50	3.58	29.20	0.82	9.0	4.99	4.81	12.3	1.06	1.05	0.9
		06/01/76	1530		23.30	21.60	5.90	32.90	0.68	8.7	4.25	4.22	17.9	1.01	1.04	-2.6
		06/01/76	2330		24.00	20.40	9.50	35.00	0.55	8.3	3.65	3.78	27.2	0.98	1.03	-5.1
		06/02/76	0730		23.00	20.90	4.28	30.40	0.55	8.3	4.33	4.26	14.1	1.08	1.03	4.4
		06/02/76	1530		22.90	20.40	5.60	31.10	0.41	7.7	3.99	3.90	18.0	1.05	1.02	2.6
		06/02/76	2330		22.90	19.60	6.30	30.80	0.71	6.0	4.01	4.04	20.5	1.06	1.04	1.8
		06/03/76	0730		25.90	24.40	5.70	36.20	0.70	9.3	4.07	4.03	15.8	1.02	1.04	-1.3
		06/03/76	2300		27.20	29.10	3.23	39.60	0.86	7.7	3.20	3.05	8.2	0.98	1.04	-6.0
	1818	05/28/76	2330		22.80	19.30	8.38	32.50	0.66	20.8	9.89	10.16	25.8	1.00	1.04	-3.5
		05/29/76	2330	TS	23.40	24.30	8.43	38.80	0.55	32.5	13.80	14.09	21.7	0.86	1.03	-13.1
		05/30/76	2330		20.90	20.50	6.48	32.10	0.55	30.8	15.80	15.99	20.2	0.93	1.03	-10.9
	1821	05/29/76	0730		21.40	19.50	8.53	32.90	0.59	54.0		26.99	25.9	0.93	1.03	-11.2
		05/30/76	0730		22.80	22.30	6.10	34.60	0.49	55.3		26.44	17.5	0.94	1.03	-3.0
		05/31/76	0730		21.20	20.70	2.13	29.00	0.60	52.4		29.02	7.6	1.09	1.04	3.9

SOLID ANALYSES

RUN NC.	ANALY TICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXI DAT ION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
633-1A	1816	06/05/76	1530		26.80	24.10	4.68	34.80	1.01	8.7	3.87	3.78	13.4	1.10	1.05	4.2
		06/05/76	2330		25.50	23.90	4.43	34.30	1.16	8.5	3.93	3.83	12.9	1.06	1.06	2.0
		06/06/76	0730	CO2	27.70	26.70	5.03	38.40	2.76	8.4	3.27	3.19	13.1	1.03	1.13	-3.8
		06/06/76	1530		24.60	23.60	3.90	33.40	1.02	8.0	3.83	3.75	11.7	1.05	1.06	-0.4
		06/06/76	2330		25.30	24.80	3.10	34.10	1.05	8.5	4.06	3.99	9.1	1.06	1.06	0.3
		06/07/76	0730		26.50	24.20	4.75	35.00	1.02	8.3	3.67	3.61	13.6	1.08	1.05	2.6
		06/07/76	1530		27.30	27.60	4.51	39.00	1.33	9.3	3.76	3.65	11.6	1.00	1.06	-6.3
		06/07/76	2330		28.00	25.70	5.98	38.10	1.08	8.4	3.32	3.30	15.7	1.05	1.05	-0.2
		06/08/76	0730		26.90	25.50	6.93	38.80	0.99	8.9	3.59	3.53	17.9	0.99	1.05	-5.7
		06/08/76	1530	X	23.10	15.70	10.88	30.50	1.00	6.6	3.06	3.26	35.7	1.08	1.06	2.0
		06/08/76	2330		27.00	25.90	4.73	37.10	0.85	7.9	3.35	3.28	12.7	1.04	1.04	-0.3
		06/09/76	0730		26.40	24.00	5.90	35.90	1.06	8.5	3.66	3.62	16.4	1.05	1.05	-0.4
		06/09/76	1530		25.70	25.60	4.71	36.70	1.06	7.7	3.39	3.31	12.8	1.00	1.05	-5.3
		06/09/76	2330		29.30	27.20	6.61	40.60	1.06	8.0	2.91	2.87	16.3	1.03	1.05	-1.7
		06/10/76	0730		26.20	23.70	6.58	36.30	0.93	8.4	3.53	3.57	18.4	1.03	1.05	-1.6
		06/10/76	1530	SO2 TS	26.10	13.70	24.28	41.40	1.59	7.5	1.76	2.43	53.6	0.97	1.07	-10.4
		06/10/76	2330		26.90	25.10	4.53	35.90	1.21	7.6	3.29	3.21	12.5	1.07	1.06	0.6
		06/11/76	0730		24.10	21.30	5.48	33.10	1.09	10.2	4.80	4.80	19.6	1.04	1.06	-2.0
		06/11/76	1530		23.40	21.00	5.85	32.10	0.76	7.6	3.74	3.72	18.2	1.04	1.04	-0.2
		06/11/76	2330		26.20	26.80	4.31	37.80	0.68	7.8	3.38	3.28	11.4	0.99	1.03	-4.4
		06/12/76	0730		26.30	26.80	3.31	36.80	0.57	8.3	3.70	3.56	9.0	1.02	1.03	-1.3
		06/12/76	1530		27.70	29.90	3.09	39.20	1.19	7.1	2.93	2.78	7.9	1.01	1.06	-4.6
		06/12/76	2330		27.20	25.50	5.43	37.30	1.28	7.5	3.11	3.04	14.5	1.04	1.06	-2.1
		06/13/76	0730		27.00	26.50	4.68	37.60	1.22	8.2	3.44	3.33	12.4	1.02	1.06	-3.6
		06/13/76	1530		28.90	27.30	6.68	40.80	1.07	8.2	2.97	2.96	16.4	1.01	1.05	-3.6
		06/13/76	2330		29.10	26.80	8.01	41.50	0.88	8.1	2.83	2.85	19.3	1.00	1.04	-3.7
		06/14/76	0530		27.50	26.40	4.01	37.00	0.58	9.5	4.10	3.94	10.8	1.06	1.03	3.1
	1818	06/07/76	0730		26.80	25.30	3.78	35.40	1.07	20.3	9.32	8.74	10.7	1.09	1.05	2.4
	1821	06/07/76	1530		25.50	26.20	5.56	38.30	1.40	52.8		21.83	14.5	0.95	1.07	-12.2
		06/11/76	1530		22.40	19.90	4.43	29.30	0.92	53.0		27.75	15.1	1.09	1.06	3.1
634-1A	1816	06/20/76	0730		34.20	28.90	6.38	42.50	5.33	5.6	1.45	1.41	15.0	1.15	1.23	-6.9
		06/20/76	1530		35.80	35.10	0.53	44.40	3.86	4.9	1.41	1.21	1.2	1.15	1.16	-3.6
				CA	32.82	34.25	-9.58	42.23	4.78				-1.4	1.11	1.21	-8.7
		06/20/76	2330		35.10	34.50	1.18	44.30	5.26	4.4	1.21	1.05	2.7	1.13	1.22	-7.5
				CA	32.53	35.00	-0.96	42.78	4.94				-2.3	1.09	1.21	-11.5
		06/21/76	0730		36.10	35.60	2.81	47.30	4.44	4.1	0.99	0.86	5.9	1.09	1.17	-7.5
		06/21/76	1530		36.50	32.20	6.26	46.50	4.89	4.0	0.85	0.81	13.5	1.12	1.19	-6.3
		06/21/76	2330		37.00	36.10	4.68	49.80	4.64	4.1	0.81	0.72	9.4	1.06	1.17	-10.3
		06/22/76	0730		37.60	35.20	4.81	49.80	4.53	4.3	0.86	0.77	9.9	1.10	1.17	-6.3
		06/22/76	1530		38.20	36.91	3.28	49.41	4.84	4.1	1.41	0.69	6.6	1.10	1.18	-6.7
				TS	35.77	36.01	-5.40	40.73	4.84	4.1	1.41	1.14	-13.3	1.25	1.22	3.0
		06/22/76	2330		37.70	34.30	2.03	44.90	6.43	3.9	0.87	0.74	4.5	1.20	1.26	-5.2
					37.51	35.47	0.74	45.07	6.16	6.1	1.47	1.23	1.6	1.19	1.25	-5.1
		06/23/76	0730		33.30	33.00	1.56	42.80	4.96	4.3	1.32	1.17	3.6	1.11	1.21	-9.0
		06/23/76	1530		38.30	35.30	5.18	49.30	4.51	4.7	0.87	0.79	10.5	1.11	1.17	-5.2

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
634-1A	1816	06/23/76			36.72	35.10	2.28	46.15	4.51	4.7	1.15	1.01	4.9	1.14	1.18	-3.7
		06/23/76	2330		37.00	35.60	7.31	51.80	4.34	4.5	0.75	0.71	14.1	1.02	1.15	-13.0
					39.91	35.47	2.02	46.35	4.34	4.5	0.97	0.82	4.4	1.23	1.17	4.8
		06/24/76	0730		38.12	35.91	4.88	49.76	3.55	4.6	0.64	0.81	9.8	1.09	1.13	-3.3
					38.41	35.91	8.61	53.49	3.55				16.1	1.03	1.12	-9.3
		06/24/76	1530		35.84	34.38	7.34	50.31	3.19	4.7	0.94	0.90	14.6	1.02	1.12	-9.7
				TS	37.69	34.38	12.05	55.02	3.19				21.9	0.98	1.11	-13.0
		06/24/76	2330		39.13	35.10	5.48	49.35	2.91	4.1	0.86	0.71	11.1	1.13	1.11	2.2
					36.46	35.10	5.67	49.54	2.91				11.4	1.05	1.11	-5.3
		06/25/76	0730	TS	40.89	34.22	13.67	56.44	3.24	3.9	0.18	0.31	24.2	1.03	1.10	-6.8
				TS	39.79	34.22	15.31	58.08	3.24				26.4	0.98	1.10	-12.6
		06/25/76	1530		36.90	36.10	3.68	48.60	3.72	3.9	0.88	0.76	7.5	1.08	1.14	-5.5
		06/25/76	2330		39.80	37.40	0.96	47.70	4.78	3.8	0.81	0.65	2.0	1.19	1.18	0.7
		06/26/76	0730		41.10	39.20	2.01	51.00	3.52	4.6	0.84	0.65	3.9	1.15	1.13	2.2
		06/26/76	1530		37.30	36.30	3.93	49.30	2.51	5.0	1.13	1.00	8.0	1.08	1.09	-1.2
		06/26/76	2330		40.40	34.20	11.16	53.90	2.86	4.4	0.47	0.50	20.7	1.07	1.10	-2.5
		06/27/76	0730		41.00	34.90	10.21	53.70	2.82	4.2	0.46	0.47	19.0	1.09	1.10	-0.5
		06/27/76	1530		37.20	34.90	2.31	45.80	2.60	3.8	1.00	0.88	5.0	1.16	1.10	4.7
		06/27/76	2330		39.50	33.50	9.43	51.30	3.08	3.9	0.56	0.57	18.4	1.10	1.11	-0.9
		06/28/76	0730		39.90	35.90	6.93	51.80	3.26	3.9	0.60	0.55	13.4	1.10	1.11	-1.4
		06/28/76	1530		37.20	34.50	6.98	50.10	2.94	4.2	0.82	0.77	13.9	1.06	1.11	-4.4
		06/28/76	2330		36.40	33.80	3.36	45.60	3.19	4.0	1.04	0.93	7.4	1.14	1.13	1.1
		06/29/76	0730		36.00	33.20	5.21	46.70	3.25	4.1	0.99	0.92	11.1	1.10	1.13	-2.4
		06/29/76	1530		36.00	31.00	7.16	45.90	2.95	4.5	1.07	1.03	15.6	1.12	1.12	0.2
		06/29/76	2330		37.60	37.90	4.73	52.10	2.98	4.4	0.86	0.74	9.1	1.03	1.10	-7.2
		06/30/76	0730		38.20	36.40	2.81	48.30	3.05	4.5	1.02	0.88	5.9	1.13	1.11	1.3
		06/30/76	1530		37.60	36.30	4.83	50.20	2.92	4.9	1.02	0.90	9.6	1.07	1.11	-3.4
		06/30/76	2330		38.80	37.00	1.96	48.20	2.88	4.1	0.94	0.79	4.1	1.15	1.11	3.5
		07/01/76	0730		43.00	37.10	3.53	49.90	3.74				7.1	1.23	1.14	7.6
				TS	44.42	37.67	-0.29	46.79	3.05				-0.6	1.36	1.12	17.5
		07/01/76	1530		43.40	37.90	5.13	52.50	4.65	3.8	0.42	0.34	9.8	1.18	1.16	1.6
		07/01/76	2330		38.20	39.10	1.13	50.00	4.38	4.0	0.85	0.69	2.3	1.09	1.16	-6.3
		07/02/76	0730		37.50	40.40	0.51	51.00	3.85	4.4	1.00	0.78	1.0	1.05	1.14	-8.3
		07/02/76	1530		41.70	38.70	2.93	51.30	3.30	3.4	0.57	0.45	5.7	1.16	1.12	3.7
	1818	25/76/06			39.50	35.30	14.58	58.70	3.43	22.7	1.23	1.63	24.9	0.96	1.11	-15.2
		06/22/76	2330		37.50	35.70	0.78	45.40	6.16	6.1	1.47	1.21	1.7	1.18	1.25	-5.7
		06/25/76	0730	TS	40.13	34.86	7.30	50.67	3.43	22.7	1.23	3.24	14.4	1.13	1.12	0.3
		06/28/76	0730		36.90	35.70	3.68	48.30	3.07	26.4	5.68	4.92	7.6	1.15	1.12	3.0
		07/02/76	0730		49.30	41.32	2.68	54.30	4.57	22.0	3.38	2.45	4.9	1.05	1.15	-8.8
	1820	04/23/75	0700													
	1821	06/23/76	0730		31.90	30.50	0.18	38.30	5.23	57.0		19.35	0.5	1.19	1.25	-5.0
		06/28/76	1530		35.90	34.40	5.31	48.30	2.90	51.0		10.97	11.0	1.06	1.11	-4.5
		07/02/76	1530		41.50	38.30	4.91	53.40	3.60	57.0		6.38	9.2	1.11	1.12	-1.2
635-1A	1816	07/16/76	2330		40.30	31.70	5.28	44.90	5.17	7.2	1.38	1.26	11.8	1.28	1.21	5.6

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
635-1A	1816	07/17/76	0730		40.90	34.60	4.66	47.90	4.45	9.5	1.49	1.31	9.7	1.22	1.17	4.1
		07/17/76	1530		42.20	36.10	5.48	50.60	2.80	8.7	1.57	1.17	10.8	1.19	1.10	7.6
		07/17/76	2330		40.30	35.90	7.43	52.30	3.23	8.5	1.23	1.12	14.2	1.10	1.11	-1.1
		07/18/76	0730		43.20	35.30	7.63	52.70	2.80	8.1	0.92	0.83	14.9	1.17	1.10	6.3
		07/20/76	0730		39.50	34.80	4.71	48.20	3.82	8.1	1.56	1.39	9.8	1.17	1.14	2.2
		07/20/76	1530		41.20	37.30	4.48	51.10	3.28	8.4	1.58	1.15	9.8	1.15	1.12	3.0
		07/20/76	2330		41.60	37.20	2.21	48.70	3.41	9.3	1.74	1.45	4.5	1.22	1.13	7.6
		07/21/76	0730		40.60	37.70	7.58	54.70	3.59	8.3	0.98	0.87	13.9	1.05	1.12	-5.6
		07/21/76	1530		44.40	38.20	13.15	60.90	2.97	8.0	0.02	0.10	21.6	1.04	1.09	-4.6
		07/21/76	2330		45.20	39.20	11.31	60.30	1.98	8.3	0.23	0.19	18.8	1.07	1.06	1.0
		07/22/76	0730		43.60	38.40	8.61	55.60	2.79	8.4	0.63	0.56	15.2	1.10	1.09	0.9
		07/22/76	1530		43.40	40.10	8.39	58.50	2.42	8.0	0.63	0.55	14.3	1.06	1.08	-1.5
		07/22/76	2330		42.30	39.60	7.26	57.00	1.92	8.3	0.90	0.72	12.7	1.06	1.06	-0.2
		07/23/76	0730		44.10	37.70	15.18	62.30	2.60	8.2		0.03	24.4	1.01	1.08	-6.5
		07/23/76	1530		44.60	37.40	15.46	62.20	1.70	8.5		0.12	24.9	1.01	1.05	-3.9
		07/23/76	2330		45.30	35.00	18.46	62.20	3.02	8.5		-0.15	29.7	1.04	1.09	-4.7
		07/24/76	0730		44.70	34.00	16.61	59.10	2.93	8.5		0.15	28.1	1.08	1.09	-0.9
		07/24/76	1530		39.70	32.00	16.71	56.70	2.33	6.1	0.47	0.75	23.5	1.00	1.07	-7.5
		07/24/76	2330		41.40	33.10	14.43	55.80	2.99	7.8	0.46	0.63	25.9	1.06	1.13	-3.5
		07/25/76	0730		43.40	33.10	16.03	57.40	2.95	8.1	0.14	0.37	27.5	1.09	1.09	-1.3
		07/25/76	1530	X	35.70	31.10	8.33	47.20	3.19	8.0	1.75	1.73	[illegible]	1.08	1.12	-4.0
		07/25/76	2330		41.50	33.30	16.96	59.20	2.97	8.6	0.14	0.41	28.6	1.00	1.09	-3.0
		07/26/76	0730		42.40	28.20	19.26	54.50	2.94	8.5	0.15	0.61	35.3	1.11	1.10	1.1
	1821	07/17/76	1530		42.00	34.20	7.66	50.40	3.95	44.0		5.41	15.2	1.19	1.14	4.3
		07/20/76	1530		41.30	35.10	7.06	50.80	2.82	44.0		6.39	13.9	1.16	1.10	5.1
		07/21/76	1530		42.80	37.20	11.11	57.60	2.80	43.0		2.62	19.3	1.06	1.09	-2.6
		07/22/76	1530		42.30	39.50	7.66	56.40	2.25	44.0		4.75	13.6	1.02	1.07	-5.1
		07/23/76	1530		40.00	33.70	14.38	56.50	2.01	47.0		4.66	25.5	1.01	1.06	-5.3
		07/24/76	1530		39.10	33.60	13.31	55.30	2.61	47.0		5.35	24.1	1.01	1.09	-7.6
		07/25/76	1530		38.00	28.30	18.83	54.20	2.60	52.0		6.35	34.7	1.00	1.09	-8.6
636-1A	1816	07/26/76	1530		39.50	32.60	13.96	54.70	2.89	8.6	0.77	0.95	25.5	1.03	1.10	-6.3
		07/28/76	2330		42.70	34.10	10.38	53.00	2.69	8.2	0.81	0.83	19.6	1.15	1.09	5.0
		07/29/76	0730		43.70	35.90	12.33	57.20	2.58	8.9	0.40	0.49	21.6	1.09	1.08	0.8
		07/29/76	1930		41.80	34.80	10.31	53.80	2.81	9.1	0.90	0.94	19.2	1.11	1.12	1.3
		07/29/76	2330		43.70	35.40	12.46	56.70	2.87	8.3	0.38	0.45	22.0	1.10	1.09	0.7
		07/30/76	0730		43.10	33.50	13.03	54.90	2.36	7.7	0.49	0.62	23.7	1.12	1.08	3.8
		07/30/76	1530		42.90	35.70	11.58	56.20	2.64	8.1	0.54	0.58	20.6	1.09	1.09	0.4
		07/30/76	2330		40.00	34.70	7.13	50.50	3.22	8.1	1.29	1.21	14.1	1.13	1.12	1.3
		07/31/76	0730		41.70	34.20	10.46	53.20	1.76	8.1	0.93	0.96	19.7	1.12	1.05	5.3
		07/31/76	1530		46.96	33.11	18.78	60.16	3.68	8.0		-0.20	31.2	1.11	1.11	0.3
					46.96	33.29	18.37	59.98	3.68				30.6	1.12	1.11	0.5
		07/31/76	2330		43.80	34.00	13.31	56.80	3.30	8.0	0.25	0.38	23.4	1.10	1.11	-0.4
		08/01/76	0730		42.70	35.70	8.88	53.50	2.80	8.2	0.86	0.81	15.6	1.14	1.10	3.9
		08/01/76	1530		42.50	35.40	9.46	53.70	3.19	8.2	0.80	0.78	17.6	1.13	1.11	1.9

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
636-1A	1816	08/01/76	2330		44.20	35.80	10.16	54.90	3.50	8.3	0.50	0.53	18.5	1.15	1.12	2.9
		08/02/76	0730		43.38	36.69	7.72	53.58	3.20	8.5	0.01	0.77	14.4	1.16	1.11	4.1
		08/02/76	1530		43.53	36.91	8.32	54.45	3.68	8.7	0.72	0.66	15.3	1.14	1.12	1.6
		08/02/76	2330		43.43	37.72	4.76	51.90	3.48	8.3		0.58	9.2	1.19	1.12	6.1
		08/03/76	0730		43.97	38.43	4.52	52.55	3.49	8.3	0.07	0.80	8.6	1.19	1.12	6.2
		08/03/76	1530		43.38	37.82	4.58	51.85	2.91	8.4		0.95	8.8	1.19	1.10	7.7
		08/03/76	2330		43.70	39.45	4.59	53.89	3.19	9.1		0.83	8.5	1.16	1.11	4.3
		08/04/76	0730		42.85	39.32	3.55	52.69	3.47	8.1	0.17	0.38	6.7	1.16	1.12	3.5
		08/04/76	1130		44.10	39.01	5.36	54.11	3.41	7.9		0.64	9.9	1.16	1.11	4.2
	1821	07/26/76	1530		39.20	31.50	11.93	51.30	2.22	46.0		6.97	23.3	1.09	1.08	1.1
		07/29/76	1930		41.40	34.00	12.21	54.70	2.87	42.0		4.00	22.3	1.08	1.10	-1.4
		07/30/76	1530		42.00	33.50	12.13	54.00	2.80	44.0		4.21	22.5	1.11	1.09	1.4
		07/31/76	1530		42.50	34.30	12.83	55.70	3.13	46.0		3.33	23.0	1.09	1.10	-1.2
		08/01/76	1530		41.40	34.30	8.93	51.89	3.21	46.0		5.60	17.2	1.14	1.11	2.5
		08/02/76	1530		42.98	36.70	8.02	53.69	3.85	44.0		3.72	14.9	1.14	1.13	0.8
		08/03/76	1530		42.15	37.46	5.32	52.14	3.35	41.0		4.81	10.2	1.15	1.12	3.2
		08/04/76	1130		44.73	40.17	4.69	54.89	4.62	40.0		2.32	8.5	1.16	1.15	0.9
637-1A	1816	08/06/76	1930		43.96	37.84	9.34	56.63	1.92	9.2		0.64	16.5	1.11	1.06	4.2
		08/06/76	2330	TS	44.23	39.09	15.06	63.91	1.87	8.7		-0.02	23.6	0.99	1.05	-6.6
		08/07/76	0730		42.60	37.75	9.55	56.73	1.59	9.0	0.07	0.77	16.8	1.07	1.05	2.0
		08/07/76	1530		42.13	38.19	7.04	54.77	1.37	8.5		0.36	12.9	1.10	1.05	4.8
		08/07/76	2330		40.81	37.85	2.54	49.84	2.08	8.3		1.39	5.1	1.17	1.08	8.0
		08/08/76	0730		40.94	38.56	3.04	51.23	2.30	8.8	0.16	1.33	5.9	1.14	1.08	5.2
		08/08/76	1530		43.41	37.46	10.34	57.16	2.00	7.7		0.52	15.1	1.08	1.06	1.9
		08/08/76	2330		43.16	36.91	11.09	57.22	1.65	7.8		0.56	19.4	1.08	1.05	2.1
		08/09/76	0730		42.29	38.43	13.06	61.09	1.59	7.8	0.09	0.36	21.4	0.99	1.05	-6.0
		08/09/76	1530		43.72	36.30	13.11	58.48	1.95	8.3		0.42	22.4	1.07	1.06	0.9
		08/09/76	2330		42.62	38.36	10.97	56.91	1.59	8.1		0.52	18.6	1.03	1.05	-1.6
		08/10/76	0730		42.26	39.09	6.22	55.07	1.18	8.7	0.35	0.98	11.3	1.10	1.04	5.2
		08/10/76	1530		43.86	38.24	15.43	63.22	1.38	8.3		0.09	24.4	0.99	1.04	-5.5
		08/10/76	2330		41.14	37.35	8.12	54.60	1.54	8.3		0.93	14.8	1.07	1.05	1.9
		08/11/76	0730		41.80	37.39	8.21	54.94	1.87	8.2	0.15	0.88	14.9	1.09	1.06	2.2
		08/11/76	1530		43.18	37.65	9.50	56.55	1.42	8.0		0.66	16.8	1.09	1.05	4.1
		08/11/76	23 0		43.28	38.37	9.02	56.97	1.62	8.5		0.56	15.8	1.08	1.05	3.0
		08/12/76	0730		44.04	38.54	9.95	58.12	1.51	8.1	0.07	0.48	17.1	1.08	1.05	3.2
	1821	08/06/76	1930		43.72	37.77	10.04	57.24	2.42	45.0		2.73	17.5	1.09	1.08	1.2
		08/07/76	1530		43.48	38.13	7.01	54.66	1.28	45.0		4.55	12.8	1.14	1.04	3.2
		08/08/76	1530		42.71	37.08	11.17	57.51	2.06	46.0		3.22	19.4	1.06	1.07	-0.5
		08/09/76	1530		41.94	37.21	11.17	57.68	1.72	51.0		4.05	19.4	1.04	1.05	-1.6
		08/10/76	1530		42.97	39.44	14.24	63.53	1.56	50.0		1.00	22.4	0.97	1.04	-7.6
		08/11/76	1530		42.45	36.93	12.02	58.18	1.57	48.0		3.36	20.7	1.04	1.05	-0.7
638-1A	1816	08/16/76	1930		43.76	37.64	12.23	60.27	2.03	6.1		0.20	21.9	1.04	1.06	-2.4

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
638-1A	1816	08/16/76	2330		42.70	36.71	10.43	56.31	1.89	4.1		0.34	18.5	1.08	1.06	2.0
		08/17/76	0730		40.36	36.54	10.91	56.58	2.44	4.8	0.02	0.47	19.3	1.02	1.08	-5.9
		08/17/76	1530		38.14	33.29	13.17	54.78	2.09	3.9		0.52	24.0	0.99	1.07	-7.6
		08/17/76	2330		40.03	35.10	13.82	57.69	1.81	4.8		0.44	24.0	0.99	1.06	-6.7
		08/18/76	0730		39.52	36.39	7.41	52.89	1.75	4.5	0.01	0.67	14.0	1.07	1.06	0.6
		08/18/76	1530		38.38	36.19	5.88	51.11	0.44	3.6		0.69	11.5	1.07	1.02	5.3
		08/18/76	2330		37.69	33.95	9.99	52.42	2.47	4.5		0.72	19.1	1.03	1.09	-5.8
		08/19/76	0530		40.63	34.63	13.90	57.18	2.27	3.9	0.03	0.33	24.3	1.01	1.07	-5.7
		08/19/76	1600		39.20	35.10	14.56	58.43	1.21	8.1		0.80	24.9	0.96	1.04	-8.3
		08/19/76	2330		44.23	37.20	10.57	57.06	1.60	5.4		0.35	18.5	1.11	1.05	5.0
		08/20/76	0730		37.32	36.55	5.04	50.72	1.57	4.5	0.10	0.57	9.9	1.05	1.07	-1.6
		08/20/76	1530		37.70	37.41	1.49	48.25	0.72	4.6		1.04	3.1	1.12	1.03	7.9
		08/20/76	2330		38.02	36.44	3.63	49.17	1.98	4.2		0.84	7.4	1.10	1.07	2.8
		08/21/76	0730		38.49	36.29	3.99	49.35	1.90	4.2	0.01	0.81	8.1	1.11	1.07	3.9
		08/21/76	1530		43.49	36.97	14.87	60.95	1.62	4.2		0.13	24.4	1.02	1.05	-2.9
		08/21/76	2330		43.65	35.03	12.25	56.03	1.78	4.3		0.31	21.9	1.11	1.06	4.9
		08/22/76	0730		38.91	35.54	5.00	49.42	1.82	4.6	0.01	0.86	10.1	1.12	1.07	5.1
		08/22/76	1530		36.33	36.19	3.69	49.12	1.86	4.5		0.98	7.9	1.06	1.07	-1.2
		08/22/76	2330		37.91	34.31	4.26	47.14	1.98	4.4		0.95	9.0	1.15	1.08	6.2
		08/23/76	0730		40.66	35.83	8.17	52.95	2.10	4.3	0.02	0.57	15.4	1.10	1.07	2.2
		08/23/76	1530		39.69	33.93	13.57	56.04	2.03	4.3		0.46	24.2	1.01	1.07	-5.4
		08/23/76	2330	TS	39.58	35.61	12.91	57.42	2.97	4.0	2.20	0.36	22.5	0.98	1.09	-11.2
				CA	28.75	35.61	*****	32.15	2.97				-38.4	1.28	1.17	8.5
		08/24/76	0530		42.53	36.55	16.67	62.35	1.87	4.8	0.02	0.11	26.7	0.97	1.05	-6.3
	1821	08/16/76	1930		43.84	39.00	15.48	62.97	2.20	45.0	0.15	0.22	24.6	0.99	1.06	-7.0
		08/17/76	1530		38.05	33.29	8.06	49.67	2.36	46.1	9.65	3.77	16.2	1.09	1.09	0.7
		08/18/76	1530		32.05	36.19	3.88	49.11	0.33	52.2		11.25	7.9	1.11	1.01	8.5
		08/19/76	1600		38.52	32.21	20.79	61.05	1.81	49.4		3.30	34.1	0.90	1.05	-17.0
					38.32	32.21	21.04	61.30	1.76	49.4		3.30	34.3	0.89	1.05	-17.9
					40.05	32.21	14.96	55.22	1.81				27.1	1.04	1.06	-2.3
		08/20/76	1530		34.26	31.64	3.11	42.65	1.16	64.0		19.10	7.3	1.15	1.05	3.5
		08/21/76	1530		34.78	32.09	6.84	46.95	1.30	58.0		14.50	14.6	1.06	1.05	0.7
		08/22/76	1530		36.00	36.61	1.30	47.06	1.67	55.0		13.43	2.8	1.09	1.06	7.5
		08/23/76	1530		38.49	29.39	16.04	52.77	1.65	63.0		9.10	30.4	1.04	1.06	-1.5
639-1A	1816	08/24/76	1530		39.51	36.87	10.75	56.93	1.74	4.1		0.46	18.9	0.99	1.06	-6.4
		08/24/76	2330		41.53	41.96	8.50	60.94	1.50	5.3		0.35	13.9	0.97	1.04	-7.4
		08/25/76	0730		41.02	41.98	7.06	59.53	2.10	5.2	0.03	0.41	11.9	0.98	1.06	-8.2
		08/25/76	1530		41.39	42.29	5.75	58.61	1.97	4.2		0.36	9.8	1.01	1.06	-5.3
				CA	40.80	40.65	12.06	62.86	1.98	5.2		0.24	19.2	0.93	1.06	-14.1
		08/26/76	0730		46.88	39.99	18.20	68.18	1.69	5.5	0.01	-0.37	26.7	0.98	1.05	-6.5
		08/26/76	1530		42.42	37.05	14.63	60.94	1.93	3.9		0.15	24.0	0.99	1.06	-6.4
					40.70	37.05	16.02	62.33	1.93				25.7	0.93	1.06	-13.3
					42.42	37.05	14.63	60.94	1.93	3.9		0.15	24.0	0.99	1.06	-6.4

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
639-1A	1916	08/26/76	2330		43.16	37.46	16.09	62.91	1.26	4.0		0.58	25.6	0.98	1.04	-5.8
		08/27/76	0730		38.84	35.29	11.09	55.20	1.37	4.0	0.01	0.54	20.1	1.00	1.05	-4.0
		08/27/76	1530		33.23	34.45	5.25	48.31	1.12	0.0		0.00	10.9	0.98	1.04	-6.1
		08/27/76	2330		41.61	31.39	22.44	61.67	0.68	3.9		0.15	36.4	0.96	1.02	-5.9
					41.61	32.42	21.15	61.67	0.68	3.9		0.16	34.3	0.96	1.02	-5.9
		08/28/76	0730		42.88	35.47	15.36	59.69	0.91	3.8	0.05	0.20	25.7	1.03	1.03	-0.2
		08/28/76	1530		43.51	33.84	18.15	60.44	1.21	4.2		0.14	30.0	1.03	1.04	-0.8
		08/28/76	2330		42.60	33.73	16.99	59.15	0.98	3.7		0.21	28.7	1.03	1.03	-0.2
		08/29/76	0730		43.04	33.83	17.94	60.22	1.32	3.6	0.30	0.14	29.8	1.02	1.04	-1.9
		08/29/76	1530		41.29	31.38	21.31	60.53	1.22	3.8		0.18	35.2	0.97	1.04	-6.5
		08/29/76	2330		42.53	26.62	25.92	59.19	0.28	3.8		0.18	43.8	1.03	1.01	1.7
		08/30/76	0730		41.22	33.32	15.03	56.67	1.37	3.5	0.01	0.32	26.5	1.04	1.04	-0.5
		08/30/76	1530		41.80	37.13	15.05	61.46	1.39	3.7		0.17	24.5	0.97	1.04	-7.2
		08/30/76	2330		42.39	36.43	13.96	59.49	1.08	4.0		0.25	23.5	1.02	1.03	-1.6
		08/31/76	1530		39.52	37.71	9.57	56.70	1.48	4.3		0.55	16.9	0.97	1.05	-8.0
		08/31/76	2330		40.84	36.91	14.15	60.28	0.99	4.4		0.31	23.5	0.97	1.03	-6.5
		09/01/76	0530		42.71	36.19	16.62	61.85	0.96	4.0	0.02	0.14	26.9	0.99	1.03	-4.3
	1821	08/24/76	1530		40.17	35.86	13.20	58.02	1.87	52.0		4.63	22.8	0.99	1.06	-7.1
		08/25/76	1530		41.92	42.39	1.27	54.25	2.18	46.0		5.63	2.3	1.10	1.07	2.7
				TS	40.13	41.75	11.85	64.03	2.18	46.0		1.88	18.5	0.89	1.06	-18.7
				TS	42.69	42.39	16.92	69.90	2.18				24.2	0.87	1.06	-21.2
		08/26/76	1530		43.18	37.30	15.03	61.65	1.90	46.0		1.19	24.6	1.00	1.05	-5.6
				CA	39.85	37.30	12.60	59.22	1.90				21.3	0.94	1.06	-10.2
				CA	40.04	37.30	14.19	60.81	1.90	46.5	0.45	3.06	23.3	0.94	1.06	-12.4
		08/27/76			42.61	34.71	18.23	61.61	1.10	50.2	0.07	1.69	29.6	0.99	1.03	-4.6
		08/28/76	1530		40.26	32.86	14.94	56.01	1.32	45.8	0.35	4.87	26.7	1.03	1.04	-1.6
		08/29/76	1530		39.21	27.68	22.26	56.85	1.28	50.8	0.39	4.37	39.1	0.98	1.04	-5.7
		08/30/76	1530		39.06	32.97	15.54	57.15	1.51	51.0		5.37	27.9	0.98	1.05	-7.4
		08/31/76	1530		39.11	37.35	11.15	57.83	1.42	49.9	0.59	5.48	19.3	0.97	1.04	-8.2
640-1A	1816	09/02/76	1830		41.98	36.55	12.05	57.73	1.15	8.1		0.67	20.9	1.04	1.04	0.2
		09/02/76	2330		44.23	35.10	17.01	60.88	1.13	9.4		0.24	27.9	1.04	1.03	0.3
		09/03/76	0730		44.65	35.52	17.87	62.26	1.22	8.5	0.12	0.06	28.7	1.02	1.04	-1.2
		09/03/76	1530		41.63	37.82	13.49	60.76	1.49	8.5		0.47	22.2	0.98	1.04	-6.8
		09/03/76	2330		44.87	38.00	14.35	61.84	1.05	8.1		0.14	23.2	1.04	1.03	0.5
		09/04/76	0730		41.82	38.07	13.29	60.87	1.27	8.8	0.02	0.49	21.8	0.98	1.04	-5.8
		09/04/76	1530		43.49	37.08	14.84	61.18	1.15	8.1		0.23	24.3	1.01	1.03	-1.9
		09/04/76	2330		45.32	32.75	23.43	64.36	0.94	8.2		-0.20	36.4	1.01	1.03	-2.1
		09/05/76	0730		41.69	38.62	7.46	55.73	1.14	8.4	0.09	0.93	13.4	1.07	1.04	2.9
					41.69	37.71	10.15	57.28	1.14				17.7	1.04	1.04	0.3
		09/05/76	1530		43.20	38.44	10.10	58.14	1.19	7.7		0.55	17.4	1.06	1.04	2.2
		09/05/76	2330		44.06	36.91	15.16	61.29	1.11	8.4		0.23	24.7	1.03	1.03	-0.7
		09/06/76	0730		44.17	38.36	15.12	63.06	1.61	8.4	0.03	0.06	24.0	1.00	1.05	-4.6
		09/06/76	1530		41.72	36.37	15.93	61.39	1.70	7.8		0.33	26.0	0.97	1.05	-6.3
		09/06/76	2330		44.95	37.28	15.56	62.15	1.80	8.5		0.04	25.0	1.03	1.05	-2.0
		09/07/76	0730		40.25	38.30	9.86	57.35	1.41	8.8	0.19	0.32	17.2	1.00	1.04	-4.3

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
640-1A	1816	09/07/76	1530		44.44	38.13	15.99	63.64	1.36	8.6		0.01	25.1	1.00	1.04	-4.2
		09/07/76	2330		46.03	38.64	17.15	65.44	1.23	8.4		-0.26	26.2	1.00	1.03	-3.0
		09/08/76	0730		44.80	38.91	16.45	65.08	1.60	7.9	1.34	-0.14	25.3	0.99	1.04	-5.3
		09/08/76	1530		44.86	36.63	19.55	64.33	1.42	7.9		-0.11	26.8	1.00	1.04	-4.5
		09/08/76	2330		42.54	37.13	15.55	61.96	1.65	7.6		0.24	25.1	0.98	1.05	-7.0
		09/09/76	0430		45.44	36.91	19.01	65.14	1.44	7.7	0.49	-0.22	29.2	1.00	1.04	-4.5
	1821	09/03/76	1530		39.16	36.44	10.66	56.20	1.23	45.0		5.63	19.0	0.99	1.04	-4.5
		09/04/76	1530		43.27	36.43	14.60	60.13	1.24				24.3	1.03	1.04	-1.0
		09/05/76	1530		44.09	38.37	11.79	59.74	1.39	50.0		2.19	19.7	1.05	1.04	1.1
		09/06/76	1530		41.40	36.91	12.52	58.65	1.51	49.0		3.76	21.3	1.01	1.05	-3.9
		09/09/76	1530		44.41	37.61	14.92	61.92	1.36	48.0		0.32	24.1	1.02	1.04	-1.6
641-1A	1816	09/09/76	1600	X	43.13	34.91	17.69	61.31	1.36	8.5		0.25	28.8	1.00	1.04	-3.6
		09/09/76	2330	X	43.55	35.80	16.26	61.00	1.29	7.2		0.22	26.7	1.02	1.04	-1.9
		09/10/76	0730		42.87	35.65	15.27	59.83	1.74	7.5	0.09	0.34	25.5	1.02	1.05	-2.9
		09/10/76	1530		45.10	37.82	13.58	60.85	1.73	8.0		0.14	22.3	1.04	1.05	0.6
		09/10/76	2330		45.37	39.42	12.48	61.75	1.52	8.2		0.10	20.2	1.05	1.04	0.4
		09/11/76	0730		40.73	40.97	6.11	57.31	1.49	8.2	0.16	0.88	10.7	1.01	1.05	-3.2
		09/11/76	1530		40.62	41.44	5.05	56.84	1.47	7.9		0.90	8.9	1.02	1.05	-2.6
		09/11/76	2330		42.08	42.38	6.30	59.27	1.48	8.2		0.64	10.6	1.01	1.05	-3.1
		09/12/76	0730		41.41	42.71	5.42	58.60	1.52	8.5	0.14	0.76	9.2	1.01	1.05	-4.1
		09/12/76	1530		42.54	42.34	6.81	59.73	1.24	7.9		0.56	11.4	1.02	1.04	-2.1
		09/12/76	2330		42.17	41.30	8.38	60.00	1.54	8.1		0.54	14.0	1.00	1.05	-4.3
		09/13/76	0730		40.14	39.92	7.07	56.96	0.63	8.1	0.04	0.97	12.4	1.01	1.02	-1.4
		09/13/76	1530		42.65	41.98	7.01	59.48	0.71	8.3		0.64	11.9	1.02	1.02	0.2
		09/13/76	2330		44.02	41.86	6.62	58.94	1.03	8.5		0.55	11.2	1.07	1.03	3.2
		09/14/76	0730		39.55	43.11	1.42	55.30	0.85	8.2	0.03	1.24	2.6	1.02	1.03	-0.7
		09/14/76	1530		40.55	41.26	6.06	57.63	0.62	8.1		0.93	10.5	1.00	1.02	-1.5
	1821	09/09/76	1600	X	43.83	35.70	17.63	62.25	1.35	50.0		0.75	28.3	1.01	1.04	-3.4
		09/10/76	1530		42.24	35.19	13.01	58.24	1.67	50.0		3.45	22.3	1.04	1.05	-1.6
		09/11/76	1530		41.36	37.46	11.15	57.97	1.58	14.9	44.00	1.26	19.2	1.02	1.05	-3.0
		09/12/76	1530		42.03	41.08	7.72	59.06	1.51	46.0		3.53	13.1	1.02	1.05	-3.0
		09/13/76	1530		42.76	41.62	9.68	61.70	0.74	46.0		2.39	15.7	0.99	1.02	-3.3
		09/14/76	1530		38.61	41.26	3.65	55.22	0.57	45.0		7.16	6.6	1.00	1.02	-2.1
642-1A	1816	09/15/76	1600		41.01	41.08	5.00	56.34	0.85	6.3		0.76	8.9	1.04	1.03	1.1
		09/15/76	2330		38.40	41.20	2.06	53.55	0.56	7.3		1.30	3.8	1.02	1.02	0.5
		09/16/76	0730		36.14	36.73	5.40	51.31	0.32	7.8	0.09	1.67	10.5	1.01	1.01	-0.6
		09/16/76	1530		39.10	39.45	7.13	56.43	1.39	8.1		1.07	12.6	0.99	1.04	-4.6
		09/16/76	2330		38.54	39.63	7.10	56.63	0.73	8.4		1.18	12.5	0.97	1.02	-5.3
		09/17/76	0730		37.03	35.83	3.42	48.20	0.99	8.0	0.45	1.82	7.1	1.10	1.04	5.4
		09/17/76	1530		36.79	39.23	0.48	49.51	0.65	8.0		1.83	1.0	1.06	1.02	3.5
		09/17/76	2330		40.06	40.30	7.51	58.63	0.99	8.3		0.33	12.8	0.98	1.03	-5.7
		09/18/76	0730		39.30	40.35	5.69	56.12	1.28	9.2	0.04	1.10	10.1	1.00	1.04	-4.2
		09/18/76	1530		39.65	40.68	5.14	55.98	1.02	8.7		1.12	9.2	1.01	1.03	-2.2
		09/18/76	2330		37.32	39.99	4.29	54.27	0.48	7.0		1.25	7.9	0.98	1.02	-3.5
		09/19/76	0730		40.41	41.54	2.92	54.84	0.65	8.7	0.03	1.25	5.3	1.05	1.02	2.9

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
642-1A	1816	09/19/76	1530		39.22	41.81	4.78	57.03	0.77	8.8		1.18	8.4	0.98	1.02	-4.4
		09/19/76	2330		38.78	39.88	6.66	56.50	0.74	7.6		1.06	11.9	0.98	1.02	-4.5
		09/20/76	0730		39.50	41.98	4.79	57.26	1.20	7.5	0.03	0.94	8.4	0.98	1.04	-5.4
		09/20/76	1530		39.69	38.36	9.26	57.20	1.28	8.0		0.91	16.2	0.99	1.04	-5.1
		09/20/76	2330		39.93	36.19	8.23	53.46	0.97	7.7		1.13	15.4	1.07	1.03	3.1
		09/21/76	0500		41.38	37.64	10.12	57.16	0.69	8.1	0.09	0.82	17.7	1.03	1.02	1.1
		09/22/76	1530		39.94	37.39	9.81	56.54	0.71	9.0		1.03	17.4	1.01	1.02	-1.4
		09/22/76	2330		40.73	37.12	11.18	57.57	1.08	7.7		0.76	19.4	1.01	1.03	-2.4
		09/23/76	0730		41.40	37.82	9.37	56.64	0.64	7.7	0.95	0.83	15.5	1.04	1.02	2.2
		09/23/76	1530		42.63	36.68	13.08	58.92	0.91	7.9		0.53	22.2	1.03	1.03	0.5
		09/23/76	2330		40.70	37.98	12.18	59.65	0.94	8.9		0.73	20.4	0.97	1.03	-5.6
		09/24/76	0730		41.24	35.47	13.78	58.11	0.44	7.9	0.35	0.72	23.7	1.01	1.01	-0.1
		09/24/76	1530		39.24	37.64	8.70	55.74	0.80	8.2		1.12	15.6	1.01	1.03	-2.1
		09/24/76	2330		41.37	38.42	12.44	60.46	0.78	7.7		0.54	20.6	0.98	1.02	-4.9
		09/25/76	0730		42.09	39.09	9.96	58.81	0.79	8.2	0.06	0.66	16.9	1.02	1.02	-0.3
		09/25/76	1530		43.53	39.63	12.88	62.41	0.59	8.2		0.28	20.6	1.00	1.02	-2.2
		09/25/76	2330		42.00	39.16	9.73	58.67	0.87	8.2		0.68	16.6	1.02	1.03	-0.5
		09/26/76	0730		42.62	36.73	12.82	58.73	0.70	8.5	0.06	0.61	21.8	1.04	1.02	1.4
		09/26/76	1530		41.87	36.91	12.66	58.79	0.74	8.7		0.68	21.5	1.02	1.02	-0.6
		09/26/76	2330		43.35	38.08	12.72	60.31	0.85	8.3		0.42	21.1	1.03	1.03	0.0
		09/27/76	0500		39.96	36.91	10.67	56.80	0.48	8.4	0.07	1.01	15.8	1.00	1.02	-1.1
	1821	09/15/76	1600		40.13	41.81	2.52	54.77	0.80	48.0		7.08	4.5	1.05	1.03	1.9
		09/16/76	1530		38.29	38.91	6.26	54.89	1.10	45.0		7.11	11.4	1.00	1.04	-4.1
		09/17/76	1530		43.45	38.03	18.14	65.67	0.84	49.0		-0.22	27.6	0.94	1.02	-6.3
		09/18/76	1530		39.67	38.75	8.80	57.23	0.92	47.0		5.58	15.4	0.99	1.03	-4.0
		09/19/76	1530		39.10	39.29	5.24	54.34	0.98	48.0		7.39	9.6	1.03	1.03	-0.5
		09/20/76	1530		29.65	33.09	0.07	41.43	1.29	58.0		20.82	0.2	1.02	1.06	-3.4
		09/22/76	1530		38.03	36.55	7.51	53.19	0.72	56.8	0.24	9.77	14.1	1.02	1.02	-0.4
		09/23/76	1530		38.68	34.89	10.46	54.07	0.94	53.0		7.97	19.4	1.02	1.03	-1.0
		09/24/76	1530		37.73	36.55	4.48	50.16	0.84	50.8	1.84	10.37	8.9	1.07	1.03	4.0
		09/25/76	1530		42.35	39.63	12.55	62.08	0.74	47.4	0.81	2.25	20.2	0.97	1.02	-4.9
		09/26/76	1530		38.43	36.73	11.14	57.05	0.74	49.8	1.22	6.45	19.5	0.96	1.02	-6.4
	1825	04/01/75	0700													
643-1A	1P16	09/27/76	1530	X	42.37	38.00	13.15	60.64	0.99	7.3		0.40	21.7	1.00	1.03	-3.2
		09/27/76	2330		44.60	38.18	12.47	60.19	1.20	8.8		0.31	20.7	1.06	1.04	2.0
		09/28/76	0730		43.71	39.09	13.20	62.05	1.33	7.2	0.19	0.19	21.3	1.01	1.04	-3.3
		09/28/76	1530		42.02	39.45	8.31	57.61	1.21	7.6		0.69	14.4	1.04	1.04	0.7
		09/28/76	2330		45.46	40.17	11.41	61.61	1.20	8.5		0.15	18.5	1.05	1.04	1.7
		09/29/76	0730		40.35	39.00	9.05	57.79	0.79	8.6	0.44	0.93	15.7	1.00	1.02	-2.8
		09/29/76	1530		45.54	40.17	13.61	63.81	1.04	9.1		-0.03	21.3	1.02	1.03	-1.1
		09/29/76	2330		45.54	41.26	11.59	63.16	0.96	8.2		0.05	18.4	1.03	1.03	0.2
		09/30/76	0730		45.30	40.75	13.34	64.27	1.35	8.2	0.05	-0.06	20.8	1.01	1.04	-3.2
		09/30/76	2330		44.22	40.35	12.01	62.44	0.67	7.6		0.21	19.2	1.01	1.02	-0.8
		10/01/76	0730		43.78	40.21	9.68	59.93	1.71	8.1	0.19	0.38	16.1	1.04	1.05	-0.9
		10/01/76	1530		43.79	41.08	8.50	59.84	1.67	8.0		0.40	14.2	1.04	1.05	-0.6

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
643-1A	1816	10/01/76	2330		43.33	40.53	11.08	61.73	1.91	8.0		0.25	17.9	1.00	1.06	-5.4
		10/02/76	0730		43.52	39.99	10.26	60.24	1.56	8.0	0.08	0.37	17.0	1.03	1.05	-1.5
		10/02/76	1530		44.79	41.92	9.25	61.64	1.46	7.8		0.20	15.0	1.04	1.04	-0.6
		10/02/76	2330		43.88	41.72	12.57	64.71	0.94	8.1		0.07	19.4	0.97	1.03	-6.0
		10/03/76	0730		41.85	42.34	8.11	61.03	0.72	7.6	0.08	0.53	13.3	0.98	1.02	-4.3
		10/03/76	1530		42.55	42.03	9.98	62.51	1.06	7.8		0.34	16.0	0.97	1.03	-6.1
		10/03/76	2330		45.51	41.26	12.59	64.16	0.68	8.1		0.00	19.6	1.01	1.02	-0.7
		10/04/76	0730		42.74	40.05	11.31	61.36	0.95	8.6	0.08	0.43	18.4	0.99	1.03	-3.4
		10/04/76	1530		45.29	41.59	11.45	63.43	1.06	8.7		0.05	18.1	1.02	1.03	-1.1
		10/04/76	2330		45.81	40.90	12.81	63.93	0.86	7.7		-0.03	20.0	1.02	1.02	-0.1
		10/05/76	0730		39.80	42.12	2.81	55.45	0.92	8.0	0.06	1.15	5.1	1.02	1.03	-0.5
	1821	10/01/76	1530		44.10	40.17	12.35	62.55	1.76	44.0		0.72	19.7	1.01	1.05	-4.4
		10/02/76	1530		44.21	40.89	9.64	60.74	1.56	44.0		1.63	15.9	1.04	1.05	-0.7
		10/03/76	1530		41.49	39.96	10.70	60.64	0.69	46.0		3.30	17.6	0.98	1.02	-4.5
		10/04/76	1530		45.46	40.77	12.70	63.65	0.99	42.0		0.04	19.9	1.02	1.03	-0.9

SOLID ANALYSES

RUN NC.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL Y
VFG-1A	1816	10/10/76	1730		13.03	12.84	0.02	16.07	0.77	13.3		9.75	0.1	1.16	1.09	6.1
		10/10/76	2330		27.09	26.96	2.21	35.90	0.44	9.1		3.94	6.1	1.08	1.02	5.1
		10/11/76	0730		26.67	25.69	3.81	35.92	0.19	9.1	2.85	3.97	10.6	1.05	1.01	4.8
		10/11/76	1530		22.40	20.18	4.53	29.75	0.22	8.6		4.53	15.2	1.07	1.01	5.7
		10/11/76	2330		24.11	21.68	5.72	32.82	0.37	8.6		4.14	17.4	1.05	1.02	2.7
		10/12/76	0730		26.03	23.34	5.01	34.16	0.33	7.9	2.61	3.53	14.7	1.09	1.02	6.4
		10/12/76	1530		25.18	22.98	4.01	32.73	0.22	7.8		3.71	12.3	1.10	1.01	7.8
		10/12/76	2330		28.53	27.26	4.99	39.06	0.38	8.2		3.19	12.8	1.04	1.02	2.4
		10/13/76	0730		28.01	27.93	2.82	37.73	0.38	5.3	2.64	3.80	7.5	1.06	1.02	3.9
		10/13/76	1530		27.94	24.97	5.93	37.14	0.33	8.2		3.35	16.0	1.07	1.02	5.4
		10/13/76	2330		27.80	27.63	2.50	37.03	0.66	8.1		3.35	6.7	1.07	1.03	3.7
		10/14/76	0730		28.02	27.28	2.15	36.24	0.66	8.1	2.23	3.39	5.9	1.10	1.03	6.4
		10/14/76	1530		27.78	27.07	0.89	35.72	0.66	8.1		3.47	2.5	1.11	1.03	6.9
		10/14/76	2330		28.20	29.68	3.37	40.46	0.66	8.0		3.05	8.3	1.00	1.03	-3.5
		10/15/76	0730		25.33	25.55	1.61	33.54	0.64	8.8	2.49	4.13	4.8	1.08	1.03	4.0
		10/15/76	1530		28.33	27.32	2.61	36.75	0.27	8.1		3.36	7.1	1.10	1.01	7.9
		10/15/76	2330		26.78	25.58	2.54	34.51	0.56	8.6		3.32	7.4	1.11	1.03	6.6
		10/16/76	0730		28.07	28.40	1.37	36.66	0.51	8.6	2.25	3.57	3.7	1.09	1.03	5.2
		10/16/76	1530		30.50	29.65	4.30	41.36	0.71	7.6		2.65	10.4	1.05	1.03	2.0
		10/16/76	2330		25.75	27.01	1.98	35.74	0.72	9.0		3.92	5.5	1.07	1.04	3.0
		10/17/76	0730		26.70	26.60	1.30	35.14	0.40	8.3	2.59	3.69	5.4	1.06	1.02	5.9
		10/17/76	1530		27.57	29.00	1.28	37.52	0.44	8.6		3.59	3.4	1.05	1.02	2.6
		10/17/76	2330		26.27	26.06	2.69	35.26	0.49	8.5		3.78	7.6	1.06	1.03	3.6
	1821	10/11/76	1530		25.73	26.23	2.73	35.51	0.26	52.0		23.43	7.7	1.03	1.01	2.0
		10/12/76	1530		25.77	21.89	6.07	33.43	0.33	53.0		22.97	18.2	1.10	1.02	7.5
		10/13/76	1530		25.98	26.06	1.73	34.30	0.49	49.0		22.42	5.0	1.08	1.03	5.1
		10/14/76	1530		28.09	28.95	1.23	37.47	0.82	50.0		20.43	3.4	1.07	1.04	2.8
		10/15/76	1530		22.12	14.61	10.70	28.96	0.27	50.0		26.15	36.9	1.09	1.02	6.7
					22.12	15.30	9.90	29.02	0.27				34.1	1.09	1.02	6.5
		10/16/76	1530		27.19	28.06	1.45	36.52	0.49	52.0		22.25	4.0	1.05	1.02	7.6
		10/17/76	1530		24.45	25.49	0.86	32.72	0.49	59.0		28.73	2.6	1.07	1.03	7.7
VFG-1B	1816	10/21/76	0730		37.41	35.65	1.28	45.84	4.12	8.8	0.18	1.90	2.8	1.17	1.16	6.1
		10/21/76	1530		36.12	34.74	0.68	44.10	3.52	7.8		1.95	1.5	1.17	1.15	2.1
		10/21/76	2330		35.69	36.26	1.03	46.35	3.25	8.9		2.12	2.2	1.10	1.13	-2.6
		10/22/76	0730		36.08	35.47	0.69	45.02	2.03	8.3	0.15	2.14	1.5	1.14	1.08	5.4
		10/22/76	1530		35.80	33.48	2.00	43.84	2.91	8.4		2.17	4.6	1.17	1.12	3.9
		10/22/76	2330		36.44	35.83	0.44	45.22	2.01	8.2		2.07	1.0	1.15	1.08	6.0
		10/23/76	0730		37.12	36.73	-1.32	44.59	1.37	8.5	0.08	2.22	-2.9	1.19	1.06	11.2
					37.15	38.00	-2.82	44.67	1.48				-6.3	1.19	1.06	10.7
		10/23/76	1530		37.64	36.91	1.68	47.81	2.36	9.1		1.95	3.5	1.12	1.09	3.0
		10/23/76	2330		38.00	36.49	0.16	45.77	2.50	8.6		1.97	0.4	1.19	1.10	7.2
		10/24/76	0730		39.42	37.28	0.40	46.99	2.01	8.5	0.04	1.70	0.8	1.20	1.11	7.1
		10/24/76	1530		40.48	36.91	2.74	48.87	2.42	8.5		1.48	5.6	1.18	1.09	7.8
		10/24/76	2330		42.38	37.35	4.08	50.76	2.70	8.6		1.16	8.0	1.19	1.10	8.0
		10/25/76	0730		41.54	38.36	2.92	50.86	2.36	8.8	0.19	1.31	5.7	1.17	1.08	7.0

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
VFG-1B	1816	10/25/76	1530		41.87	37.82	4.11	51.38	1.98	8.4		1.17	8.0	1.16	1.07	8.3
		10/25/76	2330		41.82	38.61	3.48	51.73	2.00	8.6		1.21	6.7	1.15	1.07	7.3
		10/26/76	0730		42.62	38.65	2.83	51.13	3.04	8.5	0.10	1.09	5.5	1.19	1.11	6.9
		10/26/76	1530		42.22	37.25	5.18	51.74	2.20	8.1		1.07	10.9	1.16	1.08	7.5
		10/26/76	2330		40.49	37.97	1.20	48.65	2.20	7.8		1.42	2.5	1.19	1.08	8.9
		10/27/76	0730		41.96	36.80	5.70	51.69	1.93	8.3		1.14	11.0	1.16	1.06	8.2
		10/27/76	1530		40.26	34.00	6.93	49.42	1.71	7.9		1.35	14.0	1.16	1.06	8.5
		10/27/76	2330		41.12	35.33	4.79	50.20	1.95	8.0		1.27	9.6	1.17	1.07	8.4
		10/28/76	0730		40.42	37.06	3.54	49.86	2.26	8.0	0.18	1.34	7.1	1.16	1.09	6.5
		10/28/76	1530		38.77	35.80	7.61	52.35	1.49	8.2		1.34	14.5	1.06	1.05	0.5
		10/28/76	2330		37.31	37.79	3.07	50.30	1.65	8.2		1.65	6.1	1.06	1.05	-0.1
		10/29/76	0730		38.87	36.00	5.49	50.48	2.00	8.6	0.28	1.52	10.9	1.10	1.07	2.5
	1821	10/22/76	1530		37.79	35.12	3.69	47.58	2.53	64.0		13.35	7.7	1.13	1.10	7.3
		10/23/76	1530		37.21	35.19	1.84	47.07	2.47	52.0		11.53	3.9	1.13	1.10	2.9
		10/24/76	1530		40.49	37.28	1.11	47.70	2.37	48.0		8.72	2.3	1.21	1.11	6.1
		10/25/76	1530		42.23	37.64	5.69	52.73	1.98	42.0		5.24	10.8	1.14	1.07	5.6
VFG-1C	1816	10/29/76	1530		34.83	32.55	2.46	43.14	2.01	9.3		2.62	5.7	1.15	1.08	5.9
		10/29/76	2330		28.54	25.69	4.01	36.12	0.88	9.8		4.01	11.1	1.13	1.04	7.4
		10/30/76	0730		25.96	24.25	3.89	34.20	2.11	9.0	2.58	3.94	11.4	1.08	1.11	-2.6
		10/30/76	1530		22.29	21.27	0.79	27.37	1.12	8.6		4.69	2.9	1.16	1.07	7.6
		10/30/76	2330		22.47	19.18	3.22	27.19	1.54	8.3		4.45	11.8	1.19	1.10	6.5
		10/31/76	2330		22.53	20.26	2.26	27.58	1.70	8.1		4.31	8.2	1.17	1.11	4.6
		11/01/76	0730		23.84	21.20	3.65	30.15	1.59	9.3	3.36	4.62	12.1	1.13	1.10	2.9
		11/01/76	1530		20.36	18.82	0.55	24.07	2.47	8.3		4.80	2.3	1.21	1.19	1.7
		11/01/76	2330		20.75	19.54	1.29	25.71	1.04	9.5		4.88	5.0	1.15	1.07	6.8
		11/02/76	0730		22.57	21.35	1.69	29.37	0.60	9.3	3.17	4.47	5.9	1.14	1.04	5.6
		11/02/76	1530		22.45	20.86	2.54	28.61	0.54	8.1		4.34	8.9	1.12	1.03	7.7
	1825	11/01/76	1530													
		11/01/76	2330													
		11/02/76	0730													
		11/02/76	1530													
VFG-1D	1816	11/02/76	2330		21.75	20.63	0.33	26.11	1.37	7.8		4.36	1.3	1.19	1.10	7.9
		11/03/76	0730		24.35	22.12	1.50	29.15	1.51	7.3	2.55	3.69	5.2	1.19	1.09	8.2
		11/03/76	1530		23.39	21.53	1.04	27.95	1.65	7.6		3.98	3.7	1.19	1.11	7.3
		11/03/76	2330		25.77	22.49	0.95	29.06	3.13	8.2		3.91	3.3	1.27	1.20	5.5
		11/04/76	0730		25.11	22.30	1.29	29.16	2.02	8.2	2.55	4.04	4.4	1.23	1.13	8.4
		11/04/76	1530		23.15	22.16	0.03	27.73	2.73	8.4		4.36	0.1	1.19	1.16	1.1
		11/04/76	2330		30.03	25.69	3.56	35.67	2.58	8.3		3.17	10.0	1.22	1.13	5.8
		11/05/76	0730		28.19	25.15	1.36	32.79	2.75	8.5	2.24	3.62	4.1	1.23	1.15	6.1
		11/05/76	1530		27.70	24.25	0.29	30.60	3.46	7.8		3.46	1.0	1.29	1.21	6.7
		11/05/76	2330		30.13	22.42	3.88	31.90	4.95	7.8		3.01	12.2	1.35	1.28	4.9
		11/06/76	0730		27.67	24.97	0.16	31.37	4.04	7.8	2.24	3.37	0.5	1.25	1.23	2.0
		11/06/76	1530		27.40	17.73	7.38	29.54	3.96	8.2		3.57	25.0	1.32	1.24	6.1
	1825	11/02/76	2330													

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
VFG-1D	1825	11/03/76	0730													
		11/03/76	1530													
		11/03/76	2330													
		11/04/76	0730													
		11/04/76	1530													
		11/04/76	2330													
		11/05/76	0730													
		11/05/76	1530													
		11/05/76	2330													
		11/06/76	0730													
		11/06/76	1530													
VFG-1E	1816	11/06/76	2330		26.32	18.82	4.92	28.44	4.73	8.4		3.80	17.3	1.32	1.30	1.4
		11/07/76	0730		25.15	23.70	0.53	30.15	2.36	8.2	3.01	3.96	1.8	1.19	1.14	4.1
		11/07/76	1530		21.35	19.36	1.77	25.97	1.81	8.3		4.62	6.8	1.17	1.13	4.0
		11/07/76	2330		25.41	23.96	1.51	31.46	1.63	8.0		3.80	4.8	1.15	1.09	5.1
		11/08/76	0730		22.30	20.68	0.33	26.18	1.82	8.6	3.24	4.72	1.3	1.22	1.13	7.4
		11/08/76	1530		24.14	22.80	1.99	30.49	0.98	8.3		4.17	6.5	1.13	1.05	6.9
		11/08/76	2330		28.03	26.42	0.48	33.50	1.92	8.7		3.75	1.4	1.19	1.10	7.6
		11/09/76	0730		28.89	25.25	4.98	36.54	1.68	8.9	2.68	3.49	13.6	1.13	1.09	4.0
		11/09/76	1530		28.18	23.88	6.57	36.42	2.09	8.3		3.26	18.1	1.10	1.10	0.0
		11/09/76	2330		29.37	22.98	9.23	37.95	2.14	8.1		2.94	24.3	1.10	1.10	3.2
		11/10/76	0730		27.55	24.00	6.49	36.49	2.88	8.1	2.50	3.17	17.8	1.08	1.14	-6.1
		11/10/76	1530		25.63	24.25	3.45	33.76	2.42	8.3		3.67	10.2	1.08	1.13	-4.3
	1825	11/06/76	2330													
		11/07/76	0730													
		11/07/76	1530													
		11/07/76	2330													
		11/08/76	0730													
		11/08/76	1530													
		11/08/76	2330													
		11/09/76	0730													
		11/09/76	1530													
		11/09/76	2330													
		11/10/76	0730													
		11/10/76	1530													
VFG-1F	1816	11/10/76	2330		27.51	23.91	6.52	36.40	0.33	8.2		3.42	17.9	1.08	1.02	5.8
		11/11/76	0730		18.73	17.22	1.83	23.35	1.60	12.0	5.97	7.28	7.8	1.15	1.12	1.8
		11/11/76	1530		16.77	15.64	0.64	21.44	1.43	8.2		5.29	3.0	1.12	1.12	-0.4
		11/11/76	2330		17.24	15.02	3.49	22.26	1.15	8.0		5.05	15.7	1.11	1.09	1.1
		11/12/76	0730		19.86	16.29	4.39	24.75	1.48	7.3	3.72	4.23	17.7	1.15	1.11	3.2
		11/12/76	1530		16.79	12.66	4.07	19.89	1.15	8.9		5.91	20.5	1.21	1.11	8.3
		11/12/76	2330		15.85	13.81	2.48	19.74	1.23	7.7		5.13	12.6	1.15	1.11	2.9
		11/13/76	0730		16.62	13.64	2.80	19.85	1.25	8.8	4.69	5.78	14.1	1.20	1.11	6.8
		11/15/76	1530		15.21	14.94	0.31	18.98	0.72	8.9		6.13	1.6	1.14	1.07	6.6
		11/15/76	2330		16.66	16.10	0.12	20.24	0.88	8.1		5.37	0.6	1.19	1.08	6.2

SOLID ANALYSES

RUN NC.	ANALY TICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXI DAT ION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
VFG-1F	1816	11/15/76														
		11/16/76	0730		16.90	16.28	0.93	21.28	0.82	15.0	4.52	9.76	4.4	1.13	1.07	5.6
		11/16/76	1530		19.11	18.16	0.94	23.64	1.10	8.6		5.22	4.0	1.15	1.08	6.0
		11/16/76	2330		19.18	16.56	3.31	24.01	0.98	8.0		4.80	13.8	1.14	1.07	5.8
		11/17/76	0730		17.39	15.92	0.42	20.32	2.25	7.9	3.77	5.05	2.1	1.22	1.20	1.7
		11/17/76	1530		19.14	17.94	1.38	23.80	1.15	8.7		5.25	5.8	1.15	1.09	5.2
		11/17/76	2330		19.83	18.66	0.64	23.96	1.17	9.0		5.37	2.7	1.18	1.09	7.9
		11/18/76	0730		16.31	13.39	2.78	19.51	1.10	7.6	3.92	5.05	14.2	1.19	1.10	7.6
	1825	11/10/76	2330													
		11/11/76	0730													
		11/11/76	1530													
		11/11/76	2330													
		11/12/76	0730													
		11/12/76	1530													
		11/12/76	2330													
		11/13/76	0730													
		11/15/76	1530													
		11/15/76	2330													
		11/16/76	0730													
		11/16/76	1530													
		11/16/76	2330													
		11/17/76	0730													
		11/17/76	1530													
		11/17/76	2330													
		11/18/76	0730													
VFG-1G	1816	11/18/76	1730		18.13	14.84	0.47	19.02	2.96	8.1		5.16	2.5	1.36	1.27	6.4
		11/18/76	2330		19.05	14.04	1.34	18.89	3.63	8.9		5.51	7.1	1.44	1.35	6.7
		11/19/76	0800		29.24	23.28	1.20	31.13	3.57	8.2	3.77	3.53	4.1	1.30	1.21	6.7
		11/19/76	1530		27.63	24.97	0.26	31.47	3.90	9.1		3.50	0.3	1.25	1.23	2.2
		11/19/76	2330		24.88	21.71	3.89	31.02	2.80	8.3		3.38	12.5	1.15	1.16	-1.7
		11/20/76	0730		23.63	19.90	3.75	28.62	3.30	8.6	3.20	4.25	13.1	1.18	1.21	-2.6
		11/20/76	1530		26.58	23.16	2.50	31.45	2.03	7.2		3.23	8.0	1.21	1.12	7.4
		11/20/76	2330		27.91	25.69	2.57	34.68	2.80	8.8		3.61	7.4	1.15	1.15	0.2
		11/21/76	0730		25.04	23.16	0.43	29.38	3.13	8.9	3.48	4.29	1.5	1.22	1.19	1.9
	1825	11/18/76	1730													
		11/18/76	2330													
		11/19/76	0800													
		11/19/76	1530													
		11/19/76	2330													
		11/20/76	0730													
		11/20/76	1530													
		11/20/76	2330													
		11/21/76	0730													
VFG-1I	1816	11/22/76	1700		28.56	22.80	5.55	34.05	1.92	8.3		3.41	16.3	1.20	1.10	8.2

SOLID ANALYSES

RUN NC.	ANALY TICAL PCINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXI DAT ION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
VFG-1I	1816	11/22/76	2330		27.94	22.70	3.87	32.24	2.79	15.1		6.45	12.0	1.24	1.16	6.4
		11/23/76	0730		28.55	23.52	4.69	34.09	2.75	14.9	3.93	6.03	13.8	1.20	1.15	4.1
		11/23/76	1530		28.44	24.61	3.44	34.20	2.36	14.8		6.09	10.1	1.19	1.13	5.2
		11/23/76	2330		27.03	22.44	3.34	31.39	2.25	15.4		6.92	10.7	1.23	1.13	5.0
		11/24/76	0730		27.20	19.72	7.99	32.64	2.80	15.2	5.72	6.43	24.5	1.19	1.16	2.8
		11/24/76	1530		26.25	23.06	1.89	30.71	2.49	15.0		6.95	6.2	1.22	1.15	6.0
		11/24/76	2330		27.69	23.52	4.03	33.43	2.42	15.5		6.56	12.1	1.18	1.13	4.3
		11/25/76	0730		25.51	21.17	5.38	31.84	1.70	14.9	4.99	6.83	16.9	1.15	1.10	4.5
		11/25/76	1530		25.76	22.44	4.70	32.75	1.92	14.6		6.60	14.4	1.12	1.11	1.4
		11/25/76	2330		26.78	20.26	8.07	33.39	1.70	15.3		6.61	24.2	1.14	1.09	4.6
		11/26/76	0730		26.67	23.72	4.51	34.16	1.52	15.9	5.27	6.93	13.2	1.11	1.08	3.0
		11/26/76	1530		27.11	26.79	1.00	34.49	1.67	14.9		6.47	2.9	1.12	1.09	3.1
		11/26/76	2330		28.46	25.69	3.35	35.46	1.59	15.1		6.18	9.5	1.15	1.08	5.6
		11/27/76	0730		26.50	22.07	4.46	32.04	1.65	14.6	4.04	6.52	13.9	1.18	1.09	7.4
	1825	11/22/76	1700													
		11/22/76	2330													
		11/23/76	0730													
		11/23/76	1530													
		11/23/76	2330													
		11/24/76	0730													
		11/24/76	1530													
		11/24/76	2330													
		11/25/76	0730													
		11/25/76	1530													
		11/25/76	2330													
		11/26/76	0830													
		11/26/76	1530													
		11/26/76	2330													
		11/27/76	0730													
VFG-1P	1816	11/27/76	1530		26.97	25.44	1.56	33.35	1.85	13.4		5.92	4.7	1.15	1.10	4.6
		11/27/76	2330		24.71	23.16	1.90	30.85	1.70	10.0		4.85	6.2	1.14	1.10	3.8
		11/28/76	0730		26.11	23.47	2.83	32.16	1.70	8.5	2.40	3.90	8.8	1.16	1.10	5.4
		11/28/76	1530		26.07	21.62	5.36	32.38	1.33	8.0		3.65	16.6	1.15	1.07	6.5
		11/28/76	2330		22.33	21.35	0.06	26.74	1.54	8.2		4.49	0.2	1.19	1.10	7.3
		11/29/76	0730		23.02	22.07	1.46	29.04	1.87	8.5	2.93	4.38	5.0	1.13	1.12	1.3
		11/29/76	1530		21.61	20.42	1.95	27.47	2.41	9.5		5.09	7.1	1.12	1.16	-3.3
		11/29/76	2330		19.76	18.09	2.05	24.66	1.59	7.5		4.39	8.3	1.14	1.12	2.3
		11/30/76	0730		23.66	18.25	6.05	28.86	1.87	8.2	3.30	4.11	21.0	1.17	1.12	4.5
					23.66	18.25	6.05	28.86	1.87	8.2	3.30	4.11	21.0	1.17	1.12	4.5
		11/30/76	1530		22.72	20.58	2.62	28.34	2.58	8.1		4.17	9.2	1.14	1.17	-1.8
		11/30/76	2330		25.27	22.98	1.05	29.77	1.90	8.2		4.00	3.5	1.21	1.12	7.9
		12/01/76	0730		23.74	19.30	2.77	27.64	1.92	8.1	2.91	4.19	10.0	1.23	1.13	8.1
		12/01/76	1530		21.83	20.34	0.55	25.97	1.77	8.0		4.44	2.1	1.20	1.12	6.3
		12/01/76	2330		21.75	19.18	3.17	27.14	1.70	7.9		4.28	11.7	1.14	1.11	2.6
		12/02/76	0730		22.80	21.38	1.74	28.09	1.45	7.7	2.58	4.33	6.2	1.16	1.09	5.6

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
VFG-1P	1816	12/02/76	1530		22.79	21.11	1.71	28.09	1.78	9.1		4.79	6.1	1.16	1.12	3.7
		12/02/76	2330		23.72	19.30	5.15	29.27	1.46	8.0		4.03	17.6	1.15	1.09	5.7
		12/03/76	0730		22.58	19.54	2.73	27.15	1.37	8.4	3.09	4.52	10.1	1.19	1.09	8.0
		12/03/76	1530		22.20	19.54	3.15	27.57	1.65	8.4		4.49	11.4	1.15	1.11	3.5
		12/03/76	2330		21.38	19.72	0.90	25.55	1.59	8.5		4.79	3.5	1.19	1.11	6.8
	1825	11/27/76	1530													
		11/27/76	2330													
		11/28/76	0830													
		11/28/76	1530													
		11/28/76	2330													
		11/29/76	0730													
		11/29/76	1530													
		11/29/76	2330													
		11/30/76	0730													
		11/30/76	1530													
		11/30/76	2330													
		12/01/76	0730													
		12/01/76	1530													
		12/01/76	2330													
		12/02/76	0730													
		12/02/76	1530													
		12/02/76	2330													
		12/03/76	0730													
		12/03/76	1530													
		12/03/76	2330													
	2825	11/29/76	0700													
		11/30/76	0700													

RUN NO.	DATE	TIME	INLET MASS LOADING GR/SCF	OUTLET MASS LOADING GR/SCF	MASS LOADING REMOVAL %	INLET SO3 PPM	OUTLET SO3 PPM	SO3 REMOVAL %
VFG-1A	10/12/76	1500	4.3999	0.0440	98.96			
	10/13/76	0700	3.7458	0.0223	99.38	11.29	4.89	54.95
		1500	5.1949	0.0359	99.28	10.66	4.50	58.05
	10/14/76	0700	3.8157	0.3000	91.82	13.06	0.80	93.63
		1500	5.5001	0.0309	99.42	13.31	4.94	69.21
	10/15/76	0700				4.20	0.67	83.41
		1500	4.5428	0.0283	99.35	3.39	0.43	86.81
	10/16/76	0700	3.6588	0.0252	99.28	13.09	2.67	78.79
		1500				13.07	2.77	77.96
	10/17/76	0700				12.18	0.13	98.69
		1500				14.77	4.99	64.36
VFG-1B	10/22/76	1500		0.0070		1.94	0.67	64.08
	10/23/76	0700	0.0823	0.0029	96.34	2.73	0.48	81.71
		1500	0.0490	0.0050	89.39	2.30	0.53	76.03
	10/24/76	0700	0.0779	0.0059	92.26	1.66	0.87	45.49
		1500	0.0393	0.0067	82.27		1.18	
	10/25/76	0700	0.0958	0.0040	95.66	3.34	0.69	78.51
		1500	0.0730	0.0032	95.44	3.65	1.42	59.54
	10/26/76	0700	0.2539	0.0082	96.64	4.82	2.20	52.53
		1500		0.0030		3.63	1.55	55.59
	10/27/76	0700	0.1182	0.0033	97.10	5.60	1.91	64.53
		1500	0.3799	0.0039	98.90	5.41	3.28	39.19
	10/28/76	0700	0.4172	0.0041	98.98			
		0701	0.5891	0.0073	98.75			
		1500	0.4347	0.0029	99.31	7.24	3.97	42.97
VFG-1C	10/30/76	0700	5.2957	0.0221	99.56	5.03	0.29	94.00
		1500	4.5243	0.0218	99.53	3.02	1.73	40.42
	11/01/76	0700	9.3932	0.0179	99.78	5.46	3.80	27.62
		1500	5.4380	0.0190	99.64	10.42	0.26	97.40
	11/02/76	0700	7.0038	0.0123	99.82	12.04	6.69	42.21
		1500	6.1926	0.0143	99.76	17.06	8.02	51.11
VFG-1D	11/03/76	0700	5.7762			13.19	7.09	44.10
		1500	5.2912	0.0273	99.46	13.47	5.28	59.23
	11/04/76	0700	4.3255	0.0379	99.09	7.97	4.82	37.10
		1500	4.7747	0.0168	99.63	11.32	3.73	65.73
	11/05/76	0700	3.8907	0.0269	99.30	5.21	1.72	65.67
		1500	4.3250	0.0260	99.37			
	11/06/76	0700	3.6808	0.0181	99.49		3.38	
		1500	4.0811	0.0258	99.39	4.81		
VFG-1E	11/07/76	0700	7.4956	0.0254	99.67		13.24	
		1500	5.6477	0.0229	99.58	24.80		
	11/08/76	0700	4.0392	0.0226	99.42		9.28	
		1500	4.9583	0.0194	99.59	17.82		
	11/09/76	0700	4.3465	0.0275	99.34	11.64	2.15	81.11
		1500	3.7745	0.0309	99.15	6.91		
	11/10/76	0700	4.0798	0.0360	99.09			
		1500	6.1421	0.0265	99.55			
VFG-1F	11/11/76	0700	4.1624	0.0293	99.27	10.71	3.44	66.60
		1500	6.4000	0.0173	99.72	15.54	7.70	48.47
	11/12/76	1500	4.8369	0.0420	99.10	9.30	2.47	72.38
	11/15/76	1500	6.4137	0.0352	99.43	4.54	0.84	80.76

RUN NO.	DATE	TIME	INLET MASS LOADING GR/SCF	OUTLET MASS LOADING GR/SCF	MASS LOADING REMOVAL %	INLET SO3 PPM	OUTLET SO3 PPM	SO3 REMOVAL %
VFG-1F	11/16/76	0700	4.9601	0.0244	99.49	4.00	0.00	100.00
		1500	3.7160	0.0219	99.39	0.04	0.02	45.00
	11/17/76	0700	5.4665	0.0214	99.59	1.38	0.00	100.00
		1500				0.35	0.29	13.63
VFG-1G	11/19/76	0700	0.0211			2.50		
		1500	3.7621	0.0173	99.79	8.52	2.72	66.80
	11/20/76	0700	5.5035	0.0193	99.65			
		1500	3.9046	0.0229	99.39	15.85	5.12	66.41
VFG-1I	11/23/76	0700	6.0585	0.0358	99.39			
		0701	5.6433	0.0272	99.50	6.61	1.55	75.61
	11/24/76	0700	5.2133	0.0188	99.62	10.90	5.58	46.76
		0701				21.21	10.49	48.56
	11/25/76	0700	5.1047	0.0279	99.43	5.75	0.44	92.04
		0701	5.3004	0.0276	99.46	10.35	1.53	84.65
	11/26/76	0700	3.7030	0.0211	99.41	10.93	2.71	74.21
	11/27/76	0700	5.2485	0.0168	99.67	9.09	1.29	85.36
VFG-1P	11/28/76	0700				7.88	0.72	90.50
		0701				1.46	0.00	100.00
	11/29/76	0700				3.89	0.00	100.00
	11/30/76	0700	4.2523	0.0274	99.33	5.06	4.23	13.06
		0701	6.1349	0.0318	99.46		3.37	
	12/01/76	0700	5.6143	0.0238	99.56	13.91	5.02	62.47
		0701	5.3456	0.0229	99.55			
	12/02/76	0700	4.9673	0.0223	99.53	8.25	7.15	3.87
		0701	5.5881	0.0383	99.29			
		0702	5.1382	0.0342	99.31			
	12/03/76	0700	6.6560	0.0300	99.53	4.12	2.18	44.97
		0701	5.1339	0.0349	99.29	7.75	1.05	85.91

RUN NO.	DATE	TIME	BRINK CUT 1 MICRON	BRINK CUT 2 MICRON	BRINK CUT 3 MICRON	BRINK CUT 4 MICRON	BRINK CUT 5 MICRON	BRINK CUT 1 WGT,MG	BRINK CUT 2 WGT,MG	BRINK CUT 3 WGT,MG	BRINK CUT 4 WGT,MG	BRINK CUT 5 WGT.MG
VFG-1B	10/21/76	0700	2.5100	1.4900	1.0100	0.5000	0.2200	3.90	2.43	1.50	0.34	0.08
		1500	2.5500	1.5100	1.0300	0.5100	0.2400	3.44	2.44	1.28	0.74	0.28
	10/22/76	1500	5.3400	3.2800	2.2200	1.2200	0.8100	2.00	1.82	0.79	0.45	0.04
	10/23/76	1500	4.4200	2.6500	1.6300	1.0000	0.6600	1.63	1.60	0.78	0.50	0.27
	10/24/76	0700	4.3300	2.5900	1.7900	0.9600	0.6400	2.97	0.83	1.08	0.55	0.00
		1500	4.4500	2.6600	1.8400	1.0100	0.6600	3.79	2.78	1.05	0.66	0.07
	10/25/76	0700	4.2500	2.5400	1.7600	0.9600	0.6300	3.18	3.40	0.36	0.00	0.00
		1500	4.5900	2.7400	1.9000	1.0400	0.6900	2.32	2.19	1.00	0.48	0.00
	10/26/76	0700	2.5200	1.5000	1.0200	0.5100	0.2300	7.12	6.85	3.78	1.40	0.62
	10/27/76	0700	4.3900	2.6200	1.8200	0.9900	0.6500	3.06	2.44	0.62	0.70	1.08
		1500	4.5100	2.7000	1.8700	1.0200	0.6700	7.22	5.22	3.11	2.52	0.59
	10/28/76	1500	4.3200	2.5900	1.7900	0.9800	0.6400	3.93	2.83	1.07	0.61	0.09
VFG-1C	10/30/76	0700	4.0800	2.4400	1.6900	0.9200	0.6000	25.37	10.50	4.56	3.32	0.91
		1500	4.2100	2.5200	1.7400	0.9500	0.6200	20.99	11.38	3.90	1.57	0.69
	11/01/76	0700	2.3700	1.4000	0.9500	0.4600	0.1600	14.14	7.30	2.18	0.71	0.69
		1500	2.4100	1.4300	0.9700	0.4600	0.1500	25.95	6.95	2.34	1.51	1.10
	11/02/76	0700	2.3300	1.3800	0.9300	0.4400	0.1200	18.67	6.27	0.92	1.15	0.56
		1500	2.3900	1.4100	0.9600	0.4500	0.1400	16.35	5.03	1.46	0.67	0.66
VFG-1D	11/03/76	0700	5.6000	3.3500	2.3300	1.2800	0.8500	10.21	6.18	2.50	1.49	0.35
		1500	3.0700	1.8300	1.2600	0.6600	0.4000	18.61	10.43	4.19	1.42	1.02
	11/04/76	0700	2.9300	1.7400	1.2000	0.6300	0.3700	1.58	6.95	2.82	0.23	0.18
		1500	3.0000	1.7900	1.2300	0.6400	0.3800	9.23	6.72	2.74	2.40	1.28
	11/05/76	0700	3.0900	1.8400	1.2700	0.6700	0.4000	7.76	6.20	3.15	1.38	1.39
		1500	3.1100	1.8500	1.2800	0.6700	0.4100	8.68	7.56	2.94	1.09	0.83
	11/06/76	0700	3.0400	1.8100	1.2500	0.6600	0.3900	3.85	7.75	3.29	0.74	0.73
		1500	3.0800	1.8400	1.2600	0.6700	0.4000	8.80	5.31	4.23	0.93	0.97
VFG-1E	11/07/76	1500	2.3300	1.3800	0.9300	0.4400	0.1200	30.95	3.14	3.56	1.64	1.49
	11/08/76	1500	2.3100	1.3700	0.9300	0.4300	0.1100	15.20	5.01	4.58	2.43	2.16
	11/09/76	0700	2.3500	1.3900	0.9400	0.4500	0.1400	18.02	5.06	1.43	2.17	0.39
		1500	2.4600	1.4500	0.9900	0.4800	0.1800	26.10	9.62	3.96	1.95	0.32
	11/10/76	0700	2.3200	1.3700	0.9300	0.4400	0.1200	14.10	5.21	1.53	1.33	0.47
VFG-1F	11/11/76	1500	4.2500	2.5400	1.7600	0.9600	0.6300	37.47	12.70	2.73	3.33	2.17
	11/12/76	1500	4.1700	2.4900	1.7300	0.9400	0.6100	21.00	7.43	3.96	3.46	1.21
	11/15/76	1500	2.7000	1.6100	1.1000	0.5600	0.3000	14.45	8.56	3.02	2.02	0.90
	11/16/76	0700	2.6500	1.5800	1.0800	0.5500	0.2900	10.99	6.14	1.04	1.40	0.77
		1500	2.5200	1.4900	1.0200	0.5000	0.2200	17.20	9.30	3.02	0.35	0.54
	11/17/76	0700	4.3800	2.6200	1.8200	0.9900	0.6500	19.36	11.56	3.56	1.28	0.63
		1500	4.1900	2.5100	1.7300	0.9400	0.6200	26.51	18.35	4.63	1.19	1.13
VFG-1G	11/19/76	0700	4.3500	2.6000	1.8000	0.9800	0.6500	16.64	9.21	1.76	1.45	0.44
		1500	2.6900	1.6000	1.0900	0.5600	0.2900	27.33	11.50	4.05	2.66	1.04
	11/20/76	0700	4.3100	2.5800	1.7800	0.9700	0.6400	13.65	6.56	4.44	1.37	0.86
		1500	4.3200	2.5900	1.7900	0.9800	0.6400	30.06	7.59	2.59	1.13	0.63
VFG-1I	11/23/76	0700	4.1600	2.4900	1.7200	0.9360	0.6120	31.76	12.07	3.49	1.54	0.41
	11/24/76	0700	4.3300	2.5900	1.7900	0.9800	0.6400	21.52	6.54	1.37	0.77	0.59
		0701	4.4500	2.6600	1.8400	1.0100	0.6620	21.54	8.15	3.59	1.49	0.57
	11/25/76	0700	4.1900	2.5000	1.7300	0.9430	0.6170	28.55	8.55	2.53	1.62	0.74
	11/26/76	0700	4.2300	2.5400	1.7600	0.9570	0.6270	19.65	6.48	1.98	1.16	1.15
		0701	4.3100	2.5800	1.7900	0.974	0.6390	26.94	9.56	2.19	1.52	1.05
	11/27/76	0700	4.1400	2.4800	1.7200	0.9330	0.6090	32.89	10.19	3.79	1.64	0.75
VFG-1P	11/28/76	0700	3.9900	2.3900	1.6500	0.9000	0.5800	12.95	7.27	1.94	1.07	0.79
	11/30/76	0700	4.4500	2.6600	1.8400	1.0100	0.6600	19.28	6.82	1.83	1.17	0.78
	12/01/76	0700	4.1600	2.4900	1.7200	0.9380	0.6130	15.28	7.62	1.89	1.48	2.02

RUN NO.	DATE	TIME	BRINK CUT 1 MICRON	BRINK CUT 2 MICRON	BRINK CUT 3 MICRON	BRINK CUT 4 MICRON	BRINK CUT 5 MICRON	BRINK CUT 1 WGT,MG	BRINK CUT 2 WGT,MG	BRINK CUT 3 WGT,MG	BRINK CUT 4 WGT,MG	BRINK CUT 5 WGT,MG
VFG-1P	12/03/76	0700	4.1900	2.5100	1.7400	0.9500	0.6200	22.55	10.34	1.44	1.92	1.49

RUN NO.	DATE	TIME	BRINK CYCLON CATCH WGT,MG	BRINK FILTER CATCH WGT,MG	BRINK PROBE WASH WGT,MG	BRINK ISOKIN ETIC %	BRINK GRAIN LOAD GR/DSCF	BRINK IMPACT TEMP DEG. R	BRINK IMPACT PRESS. IN. HG	BRINK SAMPLE TIME MINUTE	BRINK IMPACT D.P. IN. HG
VFG-1B	10/21/76	0700	4.13	0.32	26.07			719.00	29.88	16	1.630
		1500	6.12	6.43	21.47			737.00	29.78	42	1.480
	10/22/76	1500	0.70	0.10	10.43		0.0624	770.00	29.89	80	1.890
	10/23/76	1500	1.93	4.98	8.34		0.0793	746.00	29.59	80	1.650
	10/24/76	0700	0.99	0.60	12.40		0.0810	767.00	29.53	80	1.710
		1500	0.59	0.29	12.09		0.0871	749.00	29.65	80	1.600
	10/25/76	0700	3.22	0.30	11.89		0.0724	788.00	29.50	80	1.850
		1500	2.56	0.00	12.07		0.1501	763.00	29.30	80	1.370
	10/26/76	0700	1.25	0.53	30.15		0.0633	748.00	29.64	80	1.500
	10/27/76	0700	1.17	1.35	6.40		0.0598	742.00	30.14	80	1.760
		1500	1.26	0.00	29.45	-4.26	0.1847	734.00	30.11	80	1.560
	10/28/76	1500	1.06	0.00	2.17		0.0415	754.00	30.12	80	1.840
VFG-1C	10/30/76	0700	27.04	0.70	57.74	0.00	2.3055	801.00	28.22	16	2.130
		1500	32.52	2.34	79.01	0.00	2.7050	757.00	28.12	16	1.960
	11/01/76	0700	35.93	0.61	12.73	0.00	0.5409	791.00	29.30	12	1.834
		1500	8.34	0.76	130.28	0.00	1.2493	659.00	28.46	12	1.960
	11/02/76	0700	65.47	1.30	90.58		2.0015	757.00	28.74	8	2.060
		1500	12.46	0.78	73.52		1.1544	690.00	29.14	8	2.037
VFG-1D	11/03/76	0700	44.67	0.35	60.28	0.16	5.6300	781.00	29.02	12	0.535
		1500	48.97	0.72	171.29	-6.67	8.3586	774.50	29.12	16	0.590
	11/04/76	0700	31.73	2.27	70.79	19.74	3.5127	795.50	29.09	16	0.736
		1500	16.93	41.35	94.57	5.06	5.1456	726.00	29.41	16	0.680
	11/05/76	0700	15.59	1.12	48.61	-3.54	2.6585	765.00	29.27	16	0.567
		1500	47.77	2.10	73.10	1.07	4.7023	755.50	29.22	16	0.575
	11/06/76	0700	33.32	1.64	38.87	-7.41	2.4470	767.50	29.29	16	0.630
		1500	20.18	0.70	54.49	-7.71	2.9278	724.50	29.25	16	0.633
VFG-1E	11/07/76	1500	122.37	0.97	62.81	-3.19	4.1359	741.00	29.20	16	2.120
	11/08/76	1500	68.65	1.65	41.14	7.48	2.6281	770.50	28.71	16	2.100
	11/09/76	0700	44.97	1.13	24.39	4.74	1.8397	762.00	28.65	16	1.970
		1500	62.96	1.16	117.00	-5.67	4.2494	693.00	28.56	16	1.780
	11/10/76	0700	26.16	2.88	4.28	5.38	1.0461	763.50	27.87	16	2.100
VFG-1F	11/11/76	1500	43.40	1.46	121.62	-4.36	4.1166	721.50	28.97	16	2.010
	11/12/76	1500	50.11	2.29	47.23	9.71	2.4768	748.00	29.28	16	2.130
	11/15/76	1500	44.98	1.18	54.99	-2.51	3.1038	731.00	28.97	16	1.126
	11/16/76	0700	29.33	0.65	68.85	-0.86	2.5759	801.00	28.70	16	1.372
		1500	38.70	0.93	65.72	-5.70	2.7761	724.00	29.22	16	1.550
	11/17/76	0700	47.91	1.34	54.46	6.04	2.7490	719.50	29.02	16	1.750
		1500	64.56	4.01	188.60	3.80	3.7456	741.00	28.82	16	2.070
VFG-1G	11/19/76	0700	51.89	5.04	63.15	3.12	2.9905	740.50	28.74	16	1.740
		1500	37.19	1.19	93.69	-1.39	4.7715	742.00	28.72	16	1.330
	11/20/76	0700	43.57	1.19	64.54	-8.05	2.3669	779.00	28.76	16	1.720
		1500	76.86	1.15	72.06	-1.47	3.4707	684.00	28.50	16	1.930
VFG-1H	11/23/76	0700	102.17	1.30	72.41	-13.76	4.1635	761.00	29.17	16	2.110
	11/24/76	0700	61.05	1.69	75.56	-5.39	3.2362	731.50	29.20	16	1.930
		0701	16.20	1.20	108.57	-7.35	2.9608	670.00	29.23	16	1.780
	11/25/76	0700	80.07	1.74	135.17	7.46	4.7950	735.50	28.80	16	2.090
	11/26/76	0700	59.55	0.77	45.61	-0.08	2.6030	739.50	28.40	16	1.925
		0701	97.63	1.03	56.13	-15.96	3.7927	720.00	28.40	16	1.842
	11/27/76	0700	109.80	3.84	50.97	11.55	3.7826	727.00	28.66	16	2.206
VFG-1I	11/28/76	0700	23.92	3.52	156.37	-1.06	3.2566	697.50	29.00	16	2.760
	11/30/76	0700	46.09	1.21	38.47	-7.14	2.3116	719.00	29.20	16	1.640

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                                  BRINK   BRINK   BRINK    BRINK    BRINK   BRINK   BRINK   BRINK   BRINK
RUN                               CYCLON  FILTER  PROBE    ISOKIN   GRAIN   IMPACT  IMPACT  SAMPLE  IMPACT
NO.                               CATCH   CATCH   WASH     ETIC     LOAD    TEMP    PRESS.  TIME    D.P.
NO.     DATE      TIME  WGT,MG  WGT,MG  WGT,MG     %     GR/DSCF  DEG. R  IN. HG  MINUTE  IN. HG
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VFG-1P  12/01/76  0700   96.91    2.32   96.34     0.15   3.9602  731.00   29.27      16   2.206
        12/03/76  0700   90.56    1.53   48.67    -5.43   3.2321  730.00   28.99      16   2.100
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RUN NO.	DATE	TIME	MRI CUT 1 MICRON	MRI CUT 2 MICRON	MRI CUT 3 MICRON	MRI CUT 4 MICRON	MRI CUT 5 MICRON	MRI CUT 6 MICRON	MRI CUT 7 MICRON
VFG-1A	10/12/76	0700	29.0000	14.5000	5.2000	2.3600	1.3500	0.5200	0.4000
		1500	30.5000	15.0000	5.5000	2.5300	1.4300	0.6500	0.4200
	10/13/76	0700	29.5000	14.4000	5.2500	2.4000	1.3600	0.6100	0.4000
		1500	31.0000	15.2000	5.5000	2.5000	1.4200	0.6400	0.4100
	10/14/76	1500	31.0000	15.3000	5.6000	2.5500	1.4300	0.6500	0.4200
	10/15/76	0700	32.0000	15.5000	5.7000	2.6000	1.4500	0.6800	0.4400
		1500	29.0000	14.2000	5.1500	2.3500	1.3400	0.6100	0.3900
	10/16/76	0700	29.5000	14.4000	5.3000	2.9200	1.3700	0.6300	0.4000
		1500	28.5000	14.0000	5.1500	2.3300	1.3200	0.5900	0.3800
	10/17/76	0700	36.5000	17.8000	6.5500	3.0100	1.7300	0.7900	0.5300
		1500	27.4000	13.4000	4.8500	2.2100	1.2500	0.5600	0.3600
VFG-1B	10/21/76	0700	35.0000	17.0000	6.2500	2.8500	1.6300	0.7400	0.4900
		1500	36.0000	17.5000	6.4000	2.9300	1.6800	0.7700	0.5100
	10/22/76	1500	31.9000	15.5000	5.7000	2.6000	1.4800	0.6800	0.4400
	10/23/76	0700	32.3000	15.7000	5.7700	2.6500	1.5000	0.6800	0.4400
		1500	24.3000	12.2000	4.4500	2.0100	1.1400	0.5100	0.3300
	10/24/76	0700	25.6000	12.5000	4.5500	2.0700	1.1700	0.5300	0.3400
		1500	25.9000	12.6000	4.6300	2.1000	1.1800	0.5300	0.3400
	10/25/76	0700	26.7000	13.2000	4.5000	2.1700	1.2300	0.5600	0.3500
		1500	25.0000	12.2000	4.4500	2.0000	1.1400	0.4800	0.3300
	10/26/76	0700	25.0000	12.4000	4.5000	2.0200	1.1500	0.5100	0.3300
		1500	26.5000	13.0000	4.7800	2.1700	1.2200	0.5600	0.3600
VFG-1C	10/30/76	0700	27.4000	13.4500	4.9100	2.2400	1.2700	0.5800	0.3700
		1500	31.5000	15.5000	5.6500	2.5800	1.4700	0.6800	0.4400
	11/01/76	0700	28.3000	13.9000	5.1000	2.3100	1.3100	0.5800	0.3800
		1500	29.8000	14.6000	5.3500	2.4300	1.3800	0.6300	0.4100
	11/02/76	0700	23.5000	11.6000	4.2100	1.9100	1.0800	0.4200	0.3000
		1500	30.0000	14.8000	5.3800	2.4500	1.4000	0.6400	0.4200
VFG-1D	11/03/76	0700	27.0000	13.2000	4.8200	2.2000	1.2500	0.5600	0.3600
		1500	27.0000	13.4000	4.8000	2.2200	1.1600	0.5700	0.3700
	11/04/76	1500	27.2000	13.6000	4.9500	2.2500	1.2700	0.5700	0.3700
	11/05/76	0700	43.5000	21.4000	7.8000	3.6300	2.1000	0.9800	0.6700
		1500	26.0000	12.7000	4.7000	2.1100	1.2000	0.5400	0.3500
	11/06/76	0700	25.7000	12.7000	4.6300	2.0900	1.1900	0.5300	0.3400
		1500	28.0000	13.7000	4.9500	2.2500	1.2700	0.5700	0.3700
VFG-1E	11/07/76	1500	28.5000	14.0000	5.0300	2.3500	1.3000	0.5400	0.3500
	11/08/76	0700	31.3000	15.5000	5.8000	2.6800	1.5300	0.6900	0.4400
		1500	28.5000	14.0000	5.1500	2.3500	1.4300	0.5900	0.3900
	11/09/76	0700	28.5000	14.0000	5.1500	2.3000	1.3300	0.5800	0.3800
		1500	29.4000	14.4000	5.2000	2.4000	1.3900	0.6100	0.3900
	11/10/76	0700	32.0000	15.5000	5.3000	2.6800	1.4900	0.6800	0.4500
VFG-1F	11/15/76	1500	32.3000	15.8000	5.8000	2.6800	1.5500	0.6800	0.4500
	11/16/76	0700	30.5000	15.0000	5.5300	2.5500	1.4500	0.6600	0.4300
		1500	31.0000	15.3000	5.5000	2.6000	1.4500	0.6500	0.4200
	11/17/76	0700	31.8000	15.5000	5.6800	2.4500	1.5000	0.6900	0.4500
		1500	29.5000	14.4000	5.3000	2.4000	1.3500	0.6100	0.3900
VFG-1G	11/19/76	0700	30.5000	14.7000	5.4200	2.4700	1.4000	0.6500	0.4200
		1500	29.6000	14.6000	5.3500	2.4400	1.3900	0.6300	0.3700
	11/20/76	0700	30.1000	14.8000	5.4500	2.4800	1.4200	0.6400	0.4200
		1500	34.0000	17.5000	6.0500	3.0500	1.5800	0.7300	0.4800
VFG-1I	11/23/76	0700	31.0000	15.2000	5.4000	2.5500	1.4400	0.6500	0.4600
	11/24/76	0700	30.2000	14.9700	5.4500	2.4800	1.4200	0.6400	0.4400

RUN NO.	DATE	TIME	MRI CUT 1 MICRON	MRI CUT 2 MICRON	MRI CUT 3 MICRON	MRI CUT 4 MICRON	MRI CUT 5 MICRON	MRI CUT 6 MICRON	MRI CUT 7 MICRON
VFG-II	11/24/76	0701	31.0000	15.0000	5.5000	2.5000	1.4300	0.6400	0.4200
	11/25/76	0700	29.3000	14.4000	5.2500	2.4000	1.3200	0.6200	0.4100
	11/26/76	0700	31.7000	15.5000	5.7000	2.7400	1.4800	0.6800	0.4400
		0701	29.0000	14.3000	5.2000	2.3300	1.3500	0.6100	0.3900
	11/27/76	0700	30.5000	15.2000	5.5500	2.5300	1.4400	0.5700	0.4400
VFG-1P	11/28/76	0700	31.8000	15.5000	5.7000	2.6200	1.4800	0.6800	0.4900
	11/30/76	0700	29.8000	14.6000	5.3500	2.4500	1.3900	0.6300	0.4200
	12/01/76	0700	35.0000	17.2000	6.2000	2.9000	1.6500	0.7300	0.5100
	12/03/76	0700	28.0000	14.0000	5.1000	2.3600	1.3500	0.6100	0.3900

RUN NO.	DATE	TIME	MRI CUT 1 WGT,MG	MRI CUT 2 WGT,MG	MRI CUT 3 WGT,MG	MRI CUT 4 WGT,MG	MRI CUT 5 WGT,MG	MRI CUT 6 WGT,MG	MRI CUT 7 WGT,MG
VFG-1A	10/12/76	0700	0.55	0.91	0.04	0.21	0.90	2.28	2.88
		1500	54.07	1.70	1.13	0.40	0.63	1.63	2.39
	10/13/76	0700	0.35	0.26	0.01	0.09	0.52	0.62	0.96
		1500	2.95	0.09	0.42	0.27	1.20	2.11	1.86
	10/14/76	1500	3.01	0.46	0.30	0.31	1.53	2.54	1.83
	10/15/76	0700	1.55	0.32	0.56	0.66	3.22	4.73	7.34
		1500	0.50	0.35	0.57	0.94	3.63	9.80	10.68
	10/16/76	0700	4.70	1.19	1.39	1.53	2.33	19.27	11.54
		1500	4.66	1.04	1.13	1.05	3.37	6.88	12.34
	10/17/76	0700	1.43	0.12	0.78	0.48	11.11	3.99	4.78
		1500	1.31	0.52	0.77	1.29	6.10	5.66	13.31
VFG-1B	10/21/76	0700	1.94	0.36	0.03	0.90	0.20	0.71	0.13
		1500	1.27	0.70	1.07	0.64	0.51	0.75	1.13
	10/22/76	1500	1.27	0.71	0.63	0.45	0.39	1.18	0.39
	10/23/76	0700	14.46	2.79	2.96	1.07	0.96	1.05	1.55
		1500	3.21	1.72	1.41	0.61	1.61	1.07	1.91
	10/24/76	0700	15.70	4.59	1.48	2.22	1.46	1.28	2.26
		1500	0.63	0.91	1.13	0.48	1.13	2.54	2.44
	10/25/76	0700	3.44	1.37	0.66	1.33	1.19	2.24	1.51
		1500	0.37	0.60	0.75	1.12	0.76	1.93	1.68
	10/26/76	0700	3.98	2.01	1.74	1.44	2.42	2.58	1.03
		1500	1.77	1.39	1.46	1.08	1.31	2.31	2.06
VFG-1C	10/30/76	0700	2.63	2.27	1.60	1.62	3.72	5.65	7.01
		1500	0.77	0.66	0.45	0.31	1.66	3.63	3.99
	11/01/76	0700	1.12	0.90	0.48	1.58	5.07	7.84	8.57
		1500	4.34	0.96	0.33	1.02	3.00	4.49	2.15
	11/02/76	0700	1.60	0.09	0.63	0.89	3.20	3.27	5.57
		1500	0.74	0.28	0.27	1.30	3.70	5.23	3.87
VFG-1D	11/03/76	0700	1.21	0.65	1.27	4.27	9.31	0.50	18.79
		1500	1.51	0.66	0.76	3.43	9.23	7.56	8.25
	11/04/76	1500	5.02	0.86	0.90	1.92	5.45	3.18	9.90
	11/05/76	0700	0.36	0.02	0.33	0.32	1.57	3.27	1.44
		1500	1.35	0.62	0.82	2.54	7.10	7.51	8.99
	11/06/76	0700	1.15	0.37	1.02	2.63	5.72	7.23	6.21
		1500	1.26	0.77	0.92	2.71	6.09	4.98	8.92
VFG-1E	11/07/76	1500	1.27	1.70	1.13	3.90	7.93	3.19	4.15
	11/08/76	0700	0.59	0.13	0.03	0.98	3.77	2.94	1.98
		1500	1.01	1.15	0.99	1.97	5.30	6.82	5.77
	11/09/76	0700	0.51	0.17	1.01	2.59	7.43	4.88	9.07
		1500	5.78	0.96	1.16	2.22	6.48	6.05	7.24
	11/10/76	0700	0.64	0.89	1.30	2.16	7.18	6.37	6.08
VFG-1F	11/15/76	1500	0.13	0.25	1.05	1.33	3.17	5.82	5.45
	11/16/76	0700	1.97	0.78	1.32	2.04	3.82	3.99	4.70
		1500	0.20	0.20	1.13	2.68	4.86	7.90	5.78
	11/17/76	0700	0.61	0.66	1.49	2.97	4.94	7.35	8.56
		1500	4.68	1.18	2.23	3.05	6.62	7.42	11.54
VFG-1G	11/19/76	0700	1.79	0.83	0.84	0.63	2.45	7.95	10.33
		1500	0.57	0.71	0.65	0.33	2.72	4.89	4.34
	11/20/76	0700	2.37	1.53	1.15	1.28	2.44	4.45	5.76
		1500	0.56	0.01	0.46	0.29	0.89	2.85	4.40
VFG-1I	11/23/76	0700	0.40	0.30	1.18	1.43	4.54	7.89	12.23
	11/24/76	0700	4.62	2.10	2.14	1.50	3.32	4.07	4.47

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                                 MRI     MRI     MRI     MRI     MRI     MRI     MRI
RUN                             CUT 1   CUT 2   CUT 3   CUT 4   CUT 5   CUT 6   CUT 7
NO.     DATE        TIME       WGT.MG  WGT.MG  WGT.MG  WGT.MG  WGT.MG  WGT.MG  WGT.MG
------- ---------   ----       ------  ------  ------  ------  ------  ------  ------
VFG-11  11/24/76    0701         0.73    0.31    1.95    0.55    3.95    5.85    7.37
        11/25/76    0700         0.08    0.77    2.01    1.06    3.34    3.68    8.56
        11/26/76    0700         1.64    1.69    2.10    1.34    1.65    4.69    5.83
                    0701         5.94    1.40    1.82    1.20    2.05    3.96    4.48
        11/27/76    0700         0.74    0.87    1.71    1.13    2.34    4.53    4.54
VFG-1R  11/28/76    0700         1.93    0.57    1.19    8.82   16.66   13.29   13.79
        11/30/76    0700         0.39    0.10    1.40    3.09    6.99    4.14    3.79
        12/01/76    0700         0.18    0.44    0.45    1.96    7.16    4.94    4.08
        12/03/76    0700         3.72    0.72    0.88    5.57    6.64    7.29    5.30
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RUN NO.	DATE	TIME	MRI FILTER CATCH WGT,MG	MRI PROBE WASH WGT,MG	MRI ISOKIN ETIC %	MRI GRAIN LOAD GR/DSCF	MRI METER TEMP DEG. R	MRI METER D.P. IN. HG	MRI METER CU.FT.
VFG-1A	10/12/76	0700	13.75	0.00		0.0184	542.00	30.06	17.35
		1500	11.19	0.30	5.11	0.0209	550.00	29.98	14.56
	10/13/76	0700	5.82	0.00	14.70	0.0094	523.00	29.96	14.42
		1500	22.15	0.00	-21.41	0.0196	534.00	29.90	24.59
	10/14/76	1500	21.99	0.00	-10.08	0.0134	533.00	29.74	37.01
	10/15/76	0700	34.80	0.00	-11.10	0.0229	535.00	29.74	36.54
		1500	39.26	0.00	-20.59	0.0178	526.00	29.75	56.93
	10/16/76	0700	40.79		-26.55	0.0232	523.00	30.16	53.86
		1500	37.69	0.00	-26.03	0.0183	518.00	30.10	56.30
	10/17/76	0700	26.45	0.00	-30.97	0.0211	521.00	30.27	34.76
		1500	34.13	0.00	4.39	0.0161	521.00	30.23	58.25
VFG-1B	10/21/76	0700	2.41	0.00	-44.59	0.0018	523.00	30.17	40.95
		1500	2.38	1.25		0.0036	527.00	30.06	40.13
	10/22/76	1500	2.88	5.15	-22.00	0.0039	530.00	30.20	50.48
	10/23/76	0700	2.96	7.95	-29.70	0.0113	523.00	30.08	47.56
		1500	5.20	4.27	-9.23	0.0040	525.00	29.90	80.04
	10/24/76	0700	6.62	7.81	-16.27	0.0088	533.00	29.81	76.63
		1500	4.07	1.65	-14.09	0.0030	527.00	29.81	75.52
	10/25/76	0700	2.34	10.03	-21.71	0.0057	521.00	29.01	68.62
		1500	2.78	5.32	-2.39	0.0029	520.00	29.80	78.74
	10/26/76	0700	1.98	4.27	-16.54	0.0044	521.00	30.07	72.74
		1500	2.56	9.98	-26.01	0.0051	517.00	30.10	68.38
VFG-1C	10/30/76	0700	19.68	28.31	-27.92	0.0351	520.00	29.54	31.61
		1500	16.97	1.10	-25.97	0.0193	514.00	29.59	23.11
	11/01/76	0700	24.55	8.79	-18.54	0.0206	525.00	30.27	42.76
		1500	9.39	36.55	-26.04	0.0254	526.00	30.23	37.47
	11/02/76	0700	22.57	81.18	42.61	0.0221	531.50	30.12	61.95
		1500	15.13	6.81	0.32	0.0139	530.50	30.10	41.06
VFG-1D	11/03/76	0700	21.98	6.71	-2.40	0.0192	522.30	30.02	51.42
		1500	22.71	168.19	-10.15	0.0597	525.70	29.94	48.86
	11/04/76	1500	30.93	66.04	-21.92	0.0409	506.00	30.12	44.75
	11/05/76	0700	20.98	5.04	-30.06	0.0192	517.00	30.30	25.76
		1500	27.48	18.47	-7.41	0.0216	518.00	30.19	53.02
	11/06/76	0700	25.01	4.35	-8.45	0.0150	528.00	30.17	54.24
		1500	26.74	2.39	-6.58	0.0174	528.70	30.02	47.95
VFG-1E	11/07/76	1500	22.66	6.93	-7.02	0.0171	516.00	30.52	45.57
	11/08/76	0700	28.10	4.99	-23.70	0.0156	520.50	30.37	35.83
		1500	29.91	6.09	7.66	0.0200	522.00	30.24	44.24
	11/09/76	0700	40.67	7.14	-4.33	0.0246	533.50	29.90	46.30
		1500	37.75	5.56	-9.36	0.0270	530.50	29.74	43.31
	11/10/76	0700	40.33	6.00	-29.11	0.0320	526.50	29.93	33.94
VFG-1F	11/15/76	1500	26.36	1.65	-25.33	0.0203	516.00	30.00	33.37
	11/16/76	0700	31.07	4.65	-13.62	0.0210	530.00	30.27	39.47
		1500	32.05	3.18	-21.49	0.0232	525.00	30.22	37.75
	11/17/76	0700	24.31	2.85	-31.23	0.2330	527.00	30.13	35.12
		1500	23.13	5.69	-8.91	0.0240	526.00	29.92	41.81
VFG-1G	11/19/76	0700	30.49	0.53	-5.92	0.0216	526.00	29.84	39.60
		1500	18.62	13.55	-14.94	0.0176	530.50	29.92	40.78
	11/20/76	0700	26.39	6.28	-12.01	0.0203	524.00	29.86	38.80
		1500	24.60	211.58	-25.61	0.1255	522.00	29.73	29.96
VFG-1I	11/23/76	0700	41.02	25.23	-6.46	0.0379	512.00	30.26	36.66

RUN NO.	DATE	TIME	MRI FILTER CATCH WGT,MG	MRI PROBE WASH WGT,MG	MRI ISOKINETIC %	MRI GRAIN LOAD GR/DSCF	MRI METER TEMP DEG. R	MRI METER P.P. IN. HG	MRI METER CU.FT.
VFG-11	11/24/76	0700	16.19	11.25	-3.69	0.0190	510.00	30.09	38.51
		0701	30.37	11.16	-4.26	0.0244	529.00	30.00	38.39
	11/25/76	0700	33.08	23.02	-7.36	0.0282	536.00	29.91	42.13
	11/26/76	0700	18.63	6.74	-14.54	0.0196	526.00	29.98	34.81
		0701	12.39	28.45	-2.67	0.0351	530.00	29.58	27.38
	11/27/76	0700	13.75	2.92	-9.97	0.0133	515.00	29.84	36.54
VFG-12	11/29/76	0700	58.31	83.49	6.18	0.0804	497.00	30.14	33.95
	11/30/76	0700	22.93	5.62	-0.76	0.0181	528.00	30.36	40.31
	12/01/76	0700	22.91	3.38	-23.19	0.0229	430.00	30.18	30.31
	12/03/76	0700	25.54	7.42	7.94	0.0226	538.00	30.23	43.10

TCA OPERATING CONDITIONS

RUN NO.	ALK TYPE	FLY ASH	MGO	PH CONTR POINT	GAS RATE ACFM	GAS VEL FPS	TCA LIQ RATE GPM	TCA L/G GAL/MACF	EFFLU RES TIME MIN	NO.OF HOLD TANKS	TCA TOT BED HGT	SOLID RECIRC NOM %	SOLIDS DISCH RANGE %	TCA D.P. IN. H2O	M.E.SYSTEM D.P.RANGE IN.H2O	RUN NO.
583-2A	LS	Y	N		30000	12.5	1200	49.8	3.0	1	15.0	15.0	33-41	9.5	0.45-0.53	583-2A
583-2B	LS	Y	Y		30000	12.5	1200	49.8	3.0	1	14.5	15.0	55-64	10.0	0.45-0.53	583-2B
584-2A	LS	Y	Y		30000	12.5	1200	49.8	4.1	1	14.0	15.0	32-61	9.9	0.45-0.55	584-2A
585-2A	LS	Y	Y		30000	12.5	900	37.4	4.1	1	13.5	15.0	33-36	7.8	0.53-0.58	585-2A
586-2A	LS	Y	Y		30000	12.5	1200	49.8	4.1	1	0.0	15.0	36-37	3.5	0.52-0.60	586-2A
587-2A	LS	Y	Y		30000	12.5	1200	49.8	4.1	1	13.0	8.0	30-55	10.3	0.45-0.52	587-2A
588-2A	LS	Y	Y		20500	8.6	1200	72.9	4.1	1	15.0	15.0	60-69	5.4	0.18-0.25	588-2A
589-2A	LS	Y	Y	5.40	30000	12.5	1200	49.8	4.1	1	15.0	15.0	52-61	8.8	0.45-0.52	589-2A
601-2A	L	Y	Y	7.00	30000	12.5	1200	49.8	4.1	1	14.5	8.0	54-60	8.7	0.47-0.52	601-2A
602-2A	L	Y	Y	7.00	30000	12.5	1200	49.8	4.1	1	14.5	15.0	57-60	8.3	0.49-0.51	602-2A
603-2A	L	Y	Y	7.00	30000	12.5	1200	49.8	4.1	1	14.5	8.0	58-63	8.3	0.49-0.53	603-2A
604-2A	L	Y	Y	7.00	30000	12.5	900	37.4	4.1	1	14.0	8.0	58-62	7.3	0.52-0.98	604-2A
605-2A	L	Y	Y	7.00	20500	8.6	1200	72.9	4.1	1	14.0	8.0	51-59	4.8	0.25-0.32	605-2A
606-2A	L	Y	Y	8.00	30000	12.5	900	37.4	4.1	1	14.0	8.0	57-62	6.7	0.51-0.56	606-2A
607-2A	L	Y	Y	8.00	30000	12.5	900	37.4	4.1	1	13.5	9.0	53-59	6.4	0.45-0.47	607-2A
608-2A	L	Y	Y	8.00	30000	12.5	900	37.4	4.1	1	13.5	15.0	55-60	7.2	0.49-0.54	608-2A
608-2B	L	Y	Y	8.00	30000	12.5	900	37.4	5.4	1	13.5	15.0	52-56	6.3	0.48-0.53	608-2B
609-2A	L	Y	Y	7.00	30000	12.5	900	37.4	5.4	1	13.5	8.0	55-63	6.0	0.40-0.53	609-2A
610-2A	L	Y	Y	8.00	30000	12.5	900	37.4	5.4	1	13.0	8.0	53-67	5.8	0.47-0.53	610-2A
611-2A	L	Y	Y	8.00	30000	12.5	900	37.4	4.1	1	12.5	8.0	55-65	6.6	0.48-0.53	611-2A
612-2A	L	Y	Y	8.00	30000	12.5	900	37.4	3.0	1	12.5	8.0	57-61	7.2	0.53-0.57	612-2A
613-2A	L	Y	Y	7.00	30000	12.5	1200	49.8	3.0	1	12.0	8.0	58-61	7.7	0.57-0.61	613-2A
614-2A	L	Y	Y	8.00	30000	12.5	900	37.4	16.0	1	12.0	8.0	55-61	6.9	0.45-0.60	614-2A
615-2A	L	Y	Y	7.00	30000	12.5	1200	49.8	12.0	1	11.5	8.0	59-67	7.8	0.46-0.56	615-2A
616-2A	L	Y	N	8.00	30000	12.5	1200	49.8	12.0	1	11.0	8.0	50-63	7.4	0.42-0.51	616-2A
617-2A	L	Y	N	8.00	30000	12.5	1200	49.8	12.0	1	15.0	15.0	54-60	8.6	0.42-0.49	617-2A

TCA RUN DEFINITION AND SYSTEM CONFIGURATION

RUN NO.	START DATE	START TIME	END DATE	END TIME	HOURS ON STRM	TCA NO. BEDS	TCA TOT BED HGT	TCA SPHERE TYPE	NO.OF HOLD TANKS	M.E. SYSTEM CONFIG	M.E. WASH B/T	DE-WATER SYSTEM	ALK ADDN PT.	RUN NO.
583-2A	04/15/76	1745	04/21/76	0500	131	3	15.0	FOAM	1	1-3P/OV	I/I	CL	EHT	583-2A
583-2B	04/21/76	1545	05/01/76	1100	230	3	14.5	FOAM	1	1-3P/OV	I/I	CL	EHT	583-2B
584-2A	05/03/76	2145	05/14/76	0800	236	3	14.0	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	584-2A
585-2A	05/14/76	1145	05/20/76	0745	140	3	13.5	FOAM	1	1-3P/OV	I/I	CL	DNC	585-2A
586-2A	05/20/76	1300	05/25/76	0500	110	3	0.0		1	1-3P/OV	I/I	CL	DNC	586-2A
587-2A	05/31/76	1445	06/14/76	0530	295	3	13.0	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	587-2A
588-2A	06/16/76	0945	06/21/76	0115	107	3	15.0	FOAM	1	1-3P/OV	I/I	CE	DNC	588-2A
589-2A	06/21/76	1515	07/01/76	0515	200	3	15.0	FOAM	1	1-3P/OV	I/I	CF	DNC	589-2A
601-2A	07/01/76	2045	07/12/76	0545	177	3	14.5	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	601-2A
602-2A	07/12/76	1630	07/18/76	1210	137	3	14.5	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	602-2A
603-2A	07/19/76	2330	07/26/76	2035	165	3	14.5	FOAM	1	1-3P/OV	I/I	CL/CE	EHT	603-2A
604-2A	07/28/76	1600	08/04/76	0538	158	3	14.0	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	604-2A
605-2A	08/05/76	2115	08/13/76	1235	170	3	14.0	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	605-2A
606-2A	08/13/76	1245	08/18/76	1416	122	3	14.0	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	606-2A
607-2A	08/19/76	1427	09/02/76	1645	212	3	13.5	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	607-2A
608-2A	09/03/76	1235	09/06/76	2250	84	3	13.5	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	608-2A
608-2B	09/06/76	2250	09/13/76	0715	151	3	13.5	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	608-2B
609-2A	09/13/76	1045	09/24/76	0300	259	3	13.5	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	609-2A
610-2A	09/24/76	1100	10/07/76	1350	280	3	13.0	FOAM	1	1-3P/OV	I/I	CL/F	DNC	610-2A
611-2A	10/07/76	1600	10/12/76	0500	111	3	12.5	FOAM	1	1-3P/OV	I/I	CL/F	DNC	611-2A
612-2A	10/12/76	1433	10/19/76	0905	138	3	12.5	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	612-2A
613-2A	10/18/76	1604	10/21/76	1110	67	3	12.0	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	613-2A
614-2A	10/22/76	1356	10/28/76	0845	139	3	12.0	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	614-2A
615-2A	10/28/76	1300	11/03/76	1213	110	3	11.5	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	615-2A
616-2A	11/05/76	0800	11/13/76	1000	174	3	11.0	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	616-2A
617-2A	11/15/76	1705	11/22/76	0825	158	3	15.0	FOAM	1	1-3P/OV	I/I	CL/CE	DNC	617-2A

TCA ANALYTICAL RUN SUMMARY (GASES)

RUN NO.	AVG SO2 IN PPM	MINIMUM SO2 IN PPM	MAXIMUM SO2 IN PPM	AVG SO2 OUT PPM	MINIMUM SO2 OUT PPM	MAXIMUM SO2 OUT PPM	AVG SO2 REM %	MINIMUM SO2 REM %	MAXIMUM SO2 REM %	AVG MAKE PER PASS MMOL/L	MINIMUM MAKE PER PASS MMOL/L	MAXIMUM MAKE PER PASS MMOL/L	RUN NO.
583-2A	3040	2200	3800	602	340	1000	78	66	85	12.6	9.3	15.9	583-2A
583-2B	2954	2100	3600	370	50	900	86	68	97	13.5	9.8	16.1	583-2B
584-2A	3016	2080	4000	171	40	400	93	84	98	15.0	10.2	19.1	584-2A
585-2A	2948	2400	3880	399	180	700	85	79	93	17.7	14.9	21.9	585-2A
586-2A	2877	2120	3960	538	280	1020	79	71	87	12.1	8.4	16.9	586-2A
587-2A	3059	2400	3800	194	50	540	93	82	98	15.1	12.1	18.6	587-2A
588-2A	2476	1780	3320	159	60	260	92	87	96	8.3	6.0	11.1	588-2A
589-2A	3314	2200	4360	301	110	640	90	83	95	15.8	10.7	20.6	589-2A
601-2A	2852	2520	3200	234	40	460	90	84	98	13.7	11.9	15.9	601-2A
602-2A	3134	2800	3890	341	120	440	87	84	96	14.6	12.7	19.2	602-2A
603-2A	3179	2060	4800	452	140	1200	85	72	94	14.2	9.7	18.4	603-2A
604-2A	3432	2800	4420	873	540	1400	72	65	79	17.4	15.6	20.3	604-2A
605-2A	3575	3000	4000	688	440	1000	78	72	84	10.2	9.1	11.4	605-2A
606-2A	3350	2480	4000	781	360	1140	74	68	84	17.5	14.7	20.1	606-2A
607-2A	3295	2400	3880	440	110	760	85	78	96	19.8	14.4	24.6	607-2A
608-2A	3742	3480	4240	632	340	860	81	76	90	21.5	20.5	23.2	608-2A
608-2B	3225	2280	3920	133	30	320	95	89	99	21.7	14.4	26.9	608-2B
609-2A	3130	2480	3860	619	120	920	77	69	95	17.3	13.1	23.7	609-2A
610-2A	2987	2240	3720	426	180	650	84	78	93	17.8	13.0	21.1	610-2A
611-2A	2912	2400	3520	510	340	740	80	76	85	16.6	14.3	19.1	611-2A
612-2A	3092	2800	3760	539	440	700	80	77	83	17.6	15.9	21.1	612-2A
613-2A	3280	2080	3920	511	180	780	83	78	90	14.4	10.0	16.2	613-2A
614-2A	3556	3000	4240	758	240	1080	76	72	93	19.2	15.8	23.3	614-2A
615-2A	3141	2500	3960	375	220	690	86	81	91	14.4	11.8	17.0	615-2A
616-2A	3341	2680	4000	785	440	1260	73	63	86	13.1	9.7	16.8	616-2A
617-2A	3107	2200	3600	586	260	780	79	75	87	13.0	10.1	15.0	617-2A

TCA ANALYTICAL RUN SUMMARY (GASES) - CONTINUED

RUN NO.	AVG O2 IN %	MINIMUM O2 IN %	MAXIMUM O2 IN %	AVG BOIL LOAD MEGA WATT	MINIMUM BOIL LOAD MEGA WATT	MAXIMUM BOIL LOAD MEGA WATT	RUN NO.
583-2A							583-2A
583-2B							583-2B
584-2A							584-2A
585-2A							585-2A
586-2A							586-2A
587-2A							587-2A
588-2A							588-2A
589-2A							589-2A
601-2A							601-2A
602-2A							602-2A
603-2A							603-2A
604-2A	6.4	6.0	7.0	134	113	144	604-2A
605-2A	6.0	5.2	6.8	143	128	148	605-2A
606-2A	6.8	4.4	8.5	142	110	150	606-2A
607-2A	6.1	4.5	9.8	142	103	148	607-2A
608-2A	5.9	5.0	7.6	131	54	145	608-2A
608-2B	6.6	4.7	9.0	131	100	150	608-2B
609-2A	7.0	5.0	11.2	141	112	163	609-2A
610-2A	7.2	4.9	9.5	140	115	146	610-2A
611-2A	6.3	5.2	8.0	133	100	148	611-2A
612-2A	6.3	5.0	8.1	146	141	150	612-2A
613-2A	8.2	6.1	10.3	143	136	147	613-2A
614-2A	6.7	5.2	9.0	141	114	149	614-2A
615-2A	7.4	5.7	12.5	142	94	156	615-2A
616-2A	6.4	5.0	10.5	146	80	156	616-2A
617-2A	6.6	4.5	9.1	146	101	157	617-2A

RUN SUMMARY - LIQUID ANALYTICAL DATA

CONCENTRATIONS IN LIQUID, PPM

RUN NO.	ANALYTICAL POINT	PH			CA++			MG++			SO3=			SO4=			CL-		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
583-2A	2816 2825 2831	5.54	5.37	5.75	1833	1228	2260	2637	2079	3309	415	180	904	5382	3815	7542	7090	5318	8863
583-2B	2816 2825 2831	5.32	4.98	5.70	765	644	1132	6829	5239	11359	2838	1040	7237	19588	14202	27958	4115	2304	6381
584-2A	2816 2825 2831	5.50	5.16	5.98	362	142	730	10600	5799	13878	7476	452	20807	27308	12692	32767	5012	2659	8154
585-2A	2816 2825 2831	5.36	5.21	5.54	644	435	752	10569	8599	13373	3996	1990	5428	31523	27077	32767	4176	3190	6913
586-2A	2816 2825 2831	5.34	5.16	5.54	497	222	798	9991	8199	11639	6907	2442	18545	25923	12212	32767	4368	3013	6027
587-2A	2816 2825 2831	5.35	4.98	5.90	662	218	900	9885	8279	11839	5848	2623	11534	30885	23183	32767	2027	1240	3190
588-2A	2816 2825 2831	5.41	5.12	5.78	775	624	916	11418	10139	13658	3179	904	5428	31722	26604	32767	6337	4077	9484
589-2A	2816 2825 2831	5.41	5.25	5.70	676	584	874	10534	8739	13358	3658	226	6083	32767	28273	32767	3652	1063	9561

RUN SUMMARY - LIQUID ANALYTICAL DATA (CONTINUED)

RUN NO.	ANALYTICAL POINT	TOTAL IONS, PPM			PERCENT SULFATE SATURATION			PERCENT IONIC IMBALANCE		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
583-2A	2816 2825	17592	14786	21225	139	111	187	-2.4	-6.9	2.4
583-2B	2816 2825	32767	26482	32767	111	95	175	1.6	-14.0	12.0
584-2A	2816 2825	32767	31944	32767	56	13	118	-0.3	-10.6	10.8
585-2A	2816 2825	32767	32767	32767	107	72	124	3.1	-10.2	12.3
586-2A	2816 2825	32767	32767	32767	73	26	129	2.0	-9.6	18.4
587-2A	2816 2825	32767	32767	32767	113	30	149	0.1	-13.8	14.0
588-2A	2816 2825	32767	32767	32767	122	104	159	6.9	-5.2	13.5
589-2A	2816 2825	32767	32767	32767	117	101	153	2.3	-11.2	12.1

RUN SUMMARY - LIQUID ANALYTICAL DATA

CONCENTRATIONS IN LIQUID, PPM

RUN NO.	ANALYTICAL POINT	PH AVG	PH MIN	PH MAX	CA++ AVG	CA++ MIN	CA++ MAX	MG++ AVG	MG++ MIN	MG++ MAX	SO3= AVG	SO3= MIN	SO3= MAX	SO4= AVG	SO4= MIN	SO4= MAX	CL- AVG	CL- MIN	CL- MAX
601-2A	2816	7.09	6.04	7.71	420	130	688	2537	1011	3489	478	90	1040	7967	3506	9515	1506	709	2573
	2825																		
	2831																		
602-2A	2815	6.92	6.58	7.39	351	140	788	2898	2529	3339	425	171	814	7731	6549	9272	2587	2304	3102
	2825																		
	2831																		
603-2A	2816	6.92	6.04	7.66	623	307	840	3198	2534	3759	395	203	723	8663	7599	10752	3106	2659	3988
	2825																		
	2831																		
604-2A	2816	6.89	6.61	7.11	723	624	850	3103	2874	3504	279	180	452	8308	7263	9257	3101	2304	3545
	2825																		
	2831																		
605-2A	2816	6.95	6.79	7.10	371	207	592	3063	2429	3454	394	135	678	8126	6828	9362	2694	2393	3013
	2825																		
	2831																		
606-2A	2816	7.95	7.83	8.21	716	628	836	2887	2519	3159	278	45	407	8721	7046	9525	2499	1861	2836
	2825																		
	2831																		
607-2A	2816	7.94	7.67	8.20	492	75	760	4859	3629	5979	771	271	2058	15002	9953	17594	2581	2304	3013
	2825	5.15	5.06	5.24	926	850	1034	5032	4909	5179	2701	2568	2723	16316	15026	17543	2540	2481	2659
	2831																		
608-2A	2816	7.94	7.75	8.20	593	80	944	4818	4389	5219	632	280	2284	14725	10905	16438	2312	1950	2659
	2825	5.03	5.02	5.06	805	652	1094	4961	4649	5559	2538	1899	3075	16362	13368	21964	2175	1861	2659
	2831																		
608-2B	2816	7.96	7.83	8.10	121	5	405	4928	4059	5899	2779	384	6083	11530	9438	13940	2974	1979	4431
	2825	5.84	5.48	6.19	183	55	353	4833	4509	5129	4712	2917	6468	11488	8163	13352	3332	3013	4077
	2831																		
609-2A	2816	7.01	6.82	8.11	417	64	782	3536	2809	4630	700	226	2691	9482	7290	11795	3510	2840	4609
	2825	4.96	4.83	5.08	785	169	1212	3668	2929	4369	2588	1809	4161	10067	7677	11966	3496	2461	4875
	2831																		
610-2A	2816	7.96	7.73	8.17	339	106	878	3379	2869	4069	668	271	1176	8276	7141	9684	3515	2659	5052
	2825	5.44	5.06	7.97	659	282	1082	3385	3019	3859	2105	1311	2849	8625	6815	10269	3567	2747	4743
	2831																		
611-2A	2816	7.96	7.78	8.11	859	255	1254	3873	3333	4319	300	113	520	9445	8127	10360	5186	4609	6204
	2825	5.07	4.87	5.17	1155	1048	1384	3769	3539	4329	1628	1334	1967	9667	9037	10797	5282	5052	5524
	2831																		
612-2A	2816	7.96	7.91	8.15	869	760	998	4056	3419	4629	302	90	542	9638	6964	10913	5598	4786	6027
	2825	4.91	4.58	5.24	1124	1054	1166	4290	3379	4709	2117	1809	2736	10230	9919	10742	5909	5672	6204
	2831																		
613-2A	2816	6.98	6.74	7.10	834	628	930	4101	3499	4539	278	226	361	9812	9286	10669	5554	4609	6293
	2825	4.87	4.68	5.02	1048	966	1156	3969	3549	4599	1808	1221	2193	9955	9440	10307	5140	4857	5672
	2831																		

RUN SUMMARY - LIQUID ANALYTICAL DATA (CONTINUED)

RUN NO.	ANALYTICAL POINT	TOTAL IONS, PPM AVG	TOTAL IONS, PPM MIN	TOTAL IONS, PPM MAX	PERCENT SULFATE SATURATION AVG	PERCENT SULFATE SATURATION MIN	PERCENT SULFATE SATURATION MAX	PERCENT IONIC IMBALANCE AVG	PERCENT IONIC IMBALANCE MIN	PERCENT IONIC IMBALANCE MAX
601-2A	2816 2825	12937	6075	15512	58	17	97	5.0	-10.6	15.8
602-2A	2816 2825	14061	12096	15562	43	19	93	4.9	-12.9	13.7
603-2A	2816 2825	16084	14151	18701	76	38	109	6.1	-10.2	15.1
604-2A	2816 2825	15633	14302	17408	86	75	103	9.3	3.3	15.7
605-2A	2816 2825	14754	13271	16274	46	24	79	6.7	-3.4	12.3
606-2A	2816 2825	15192	13506	16247	93	82	112	6.1	-2.4	9.8
607-2A	2816	23789	17497	27537	73	11	111	5.0	-11.6	15.6
	2825	27606	26067	29046	138	127	160	-3.4	-5.8	0.4
608-2A	2816	23170	20830	24731	87	9	135	9.3	-2.0	17.4
	2825	26934	24075	32767	125	89	194	-2.6	-14.7	4.1
608-2B	2816	22421	18206	26570	15	1	51	5.0	-6.3	14.9
	2825	24632	23061	26409	21	7	35	-10.1	-14.5	-6.8
609-2A	2816	17744	14409	21745	52	8	96	0.2	-11.7	12.9
	2825	20701	17934	23155	96	22	157	-8.4	-14.8	0.2
610-2A	2816	16285	14290	19501	40	12	105	3.1	-13.5	11.7
	2825	18447	16072	21309	77	29	134	-5.9	-12.2	-1.3
611-2A	2816	19802	18179	20907	96	30	138	4.0	-11.5	10.7
	2825	21630	20334	23237	130	120	155	-5.3	-11.9	-0.5
612-2A	2816	20620	17653	22636	96	76	109	4.1	-1.1	13.3
	2825	23836	22790	24688	123	114	139	-4.7	-9.9	3.1
613-2A	2816	20719	18779	22187	93	77	108	3.8	-4.0	10.2
	2825	22063	20233	23893	119	116	122	-4.2	-11.6	3.6

RUN SUMMARY - LIQUID ANALYTICAL DATA

CONCENTRATIONS IN LIQUID, PPM

RUN	ANALY TICAL	PH			CA++			MG++			SO3=			SO4=			CL-		
NO.	POINT	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
614-2A	2816	8.12	7.83	8.56	749	107	926	3470	2719	3900	392	248	1357	8691	8047	9791	4236	2127	5229
	2825																		
	2831																		
615-2A	2816	7.07	6.85	7.50	783	600	966	3734	3149	4109	305	113	497	9718	8017	11173	4482	3900	5140
	2825	4.95	4.77	5.07	1133	1025	1430	3690	3129	4059	1679	1176	2353	9933	8242	11053	4595	4148	5495
	2831																		
616-2A	2816	7.92	5.74	8.32	2701	1700	3255	219	80	342	136	45	339	1498	580	2200	4056	2481	5140
	2825	4.39	4.12	4.73	3108	2775	3520	229	91	375	1278	361	1854	1989	1147	3252	4106	2659	5229
	2831																		
617-2A	2816	7.99	7.70	8.14	2735	2010	3860	521	353	643	124	0	226	1560	827	1923	4588	3651	5115
	2825	4.67	4.32	7.95	3046	2600	4370	521	355	678	994	90	1402	2170	631	3279	4653	3634	6115
	2831																		

RUN SUMMARY - LIQUID ANALYTICAL DATA (CONTINUED)

RUN NO.	ANALYTICAL POINT	TOTAL IONS, PPM			PERCENT SULFATE SATURATION			PERCENT IONIC IMBALANCE		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
614-2A	2816	17849	14411	19482	86	15	104	3.2	-13.2	10.9
	2825									
615-2A	2816	19162	17489	20428	92	77	100	3.9	-7.3	10.6
	2825	21169	19578	22707	133	112	154	-4.0	-14.1	5.2
616-2A	2816	8763	6041	10208	117	50	171	5.1	-5.4	14.0
	2825	10867	8963	12165	157	94	259	-5.9	-17.0	9.5
617-2A	2816	9690	7637	12317	107	52	123	10.2	-0.9	15.1
	2825	11566	8389	14478	150	48	233	-0.6	-14.6	16.7

RUN SUMMARY - SOLIDS ANALYTICAL DATA

CONCENTRATIONS IN SOLIDS, WT %

RUN NO.	ANALYTICAL POINT	CO2			SO2			SO3			CAO			ACID INSOLUBLES			SOLIDS IN SLURRY, WT %		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
583-2A	2816 2831	3.93	1.18	6.32	18.21	13.80	22.60	9.98	6.95	14.80	28.48	25.55	30.80	5.46	3.89	6.34	14.7	13.2	15.6
583-2B	2816 2831	5.33	2.67	10.17	16.82	10.90	22.80	10.23	6.95	15.33	28.78	25.10	34.20	5.37	2.73	7.57	14.8	7.7	17.7
584-2A	2816 2831	7.46	2.39	13.44	20.60	14.50	27.40	5.51	0.83	9.88	31.86	28.00	34.70	5.38	4.30	7.68	15.4	13.0	17.9
585-2A	2816 2831	7.27	4.41	9.54	17.71	13.80	21.30	7.53	3.18	11.43	30.47	27.90	33.40	5.23	4.13	6.52	14.6	13.1	16.3
586-2A	2816 2831	6.39	5.17	9.79	18.58	14.50	21.30	7.42	0.98	11.90	29.61	24.50	31.70	5.38	3.83	7.15	14.5	12.8	15.8
587-2A	2816 2831	8.20	5.12	12.29	16.44	12.10	21.10	7.19	3.08	12.68	30.29	25.60	33.80	3.40	2.29	5.13	9.2	6.9	12.7
588-2A	2816 2831	11.75	8.83	15.40	11.50	7.20	15.30	6.47	4.10	9.55	30.99	29.00	34.80	5.28	4.64	5.78	14.2	12.9	15.1
589-2A	2816 2831	6.19	2.33	14.59	19.03	12.30	24.50	5.54	1.38	8.50	29.10	25.80	37.20	5.93	4.22	7.67	14.9	13.4	16.8

RUN SUMMARY - SOLIDS ANALYTICAL DATA (CONTINUED)

RUN NO.	ANALYTICAL POINT	PERCENT SULFITE OXIDATION			STOICHIOMETRIC RATIO			PERCENT IONIC IMBALANCE		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
583-2A	2816 2831	30.6	20.9	41.2	1.22	1.06	1.39	2.0	-3.9	7.2
583-2B	2816 2831	32.8	26.0	43.5	1.32	1.14	1.70	0.4	-8.3	8.5
584-2A	2816 2831	17.4	3.2	28.7	1.46	1.13	2.09	1.5	-7.4	7.4
585-2A	2816 2831	25.4	13.1	35.4	1.45	1.24	1.60	1.5	-3.5	7.1
586-2A	2816 2831	23.0	5.1	35.1	1.40	1.29	1.93	0.1	-4.3	7.7
587-2A	2816 2831	25.5	14.7	45.6	1.56	1.30	1.99	1.3	-7.0	8.5
588-2A	2816 2831	31.2	22.7	47.4	2.07	1.68	2.53	4.5	-1.4	8.5
589-2A	2816 2831	18.8	5.3	34.9	1.42	1.12	2.12	2.2	-3.0	7.9

RUN SUMMARY - SOLIDS ANALYTICAL DATA

CONCENTRATIONS IN SOLIDS, WT %

RUN NO.	ANALYTICAL POINT	CO2			SO2			SO3			CAO			ACID INSOLUBLES			SOLIDS IN SLURRY, WT %		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
601-2A	2816 2831	0.76	0.16	1.98	22.87	20.00	26.80	5.70	2.38	9.78	25.65	20.70	30.80	3.75	2.72	4.71	8.3	7.3	9.0
602-2A	2816 2831	0.73	0.29	1.48	24.45	21.30	27.20	4.78	0.02	9.65	25.91	23.30	28.30	6.67	3.24	8.18	14.7	8.7	16.3
603-2A	2816 2831	0.55	0.05	3.82	21.44	17.90	24.40	6.24	2.68	10.95	23.64	18.60	26.90	3.88	3.17	5.13	8.1	7.2	9.3
604-2A	2816 2831	0.30	0.05	1.10	18.59	15.20	21.30	10.00	6.98	13.63	24.22	21.50	26.71	3.43	2.58	4.15	7.7	7.1	8.3
605-2A	2816 2831	0.56	0.19	0.93	24.49	19.72	28.23	7.36	4.64	11.62	27.61	23.26	30.80	2.15	1.37	2.89	7.8	7.0	8.8
606-2A	2816 2831	0.91	0.33	2.27	20.47	16.75	25.33	7.78	3.20	17.35	24.11	20.33	31.57	2.66	2.23	3.42	8.0	7.4	9.3
607-2A	2816 2831	0.87	0.13	1.58	22.85	18.08	26.24	5.23	0.04	13.84	25.48	21.95	29.73	2.70	2.06	3.88	7.8	6.9	8.6
608-2A	2816 2831	1.17	0.82	1.55	24.61	20.81	28.84	7.33	5.23	10.01	27.80	25.24	29.86	4.36	3.99	4.59	14.7	13.4	15.7
608-2B	2816 2831	1.44	1.02	1.84	26.01	21.17	28.67	4.70	2.22	9.39	27.79	25.73	30.14	4.51	4.05	5.08	14.8	14.0	15.6
609-2A	2816 2831	0.46	0.13	0.94	23.17	18.27	28.76	4.83	0.37	9.06	24.51	19.49	30.63	2.95	2.24	3.83	8.0	7.1	8.7
610-2A	2816 2831	0.74	0.35	1.08	22.79	17.96	28.95	2.64	0.25	5.51	23.63	19.19	28.55	2.58	1.84	2.95	7.9	7.2	8.7
611-2A	2816 2831	0.68	0.16	1.54	17.32	13.46	21.89	9.68	0.64	20.73	23.57	20.44	27.70	2.63	2.33	3.03	8.0	6.9	8.9
612-2A	2816 2831	0.33	0.11	0.66	18.04	15.53	20.26	9.99	7.08	12.33	24.54	21.00	27.10	2.75	2.32	3.31	8.0	7.0	9.2
613-2A	2816 2831	0.47	0.16	0.78	17.94	14.31	25.35	10.12	1.71	17.23	24.22	19.72	28.36	2.43	1.87	3.20	8.1	6.9	8.7

RUN SUMMARY - SOLIDS ANALYTICAL DATA (CONTINUED)

RUN NO.	ANALYTICAL POINT	PERCENT SULFITE OXIDATION			STOICHIOMETRIC RATIO			PERCENT IONIC IMBALANCE		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
601-2A	2815 2831	16.3	7.8	25.1	1.04	1.01	1.10	2.5	-7.9	7.2
602-2A	2815 2831	13.1	0.1	24.8	1.04	1.01	1.08	1.0	-6.3	8.2
603-2A	2816 2831	18.6	9.5	31.0	1.03	1.00	1.25	-0.9	-8.3	8.3
604-2A	2816 2831	30.0	20.9	37.3	1.02	1.00	1.06	2.3	-7.3	8.1
605-2A	2816 2831	19.3	13.2	27.7	1.03	1.01	1.04	1.0	-7.7	7.2
606-2A	2816 2831	23.0	9.2	40.8	1.05	1.02	1.12	-1.8	-8.4	7.2
607-2A	2816 2831	15.1	0.1	31.8	1.05	1.01	1.09	2.8	-6.7	8.5
608-2A	2816 2831	19.3	12.7	26.2	1.06	1.04	1.07	-1.3	-5.6	1.6
608-2B	2816 2831	12.5	6.5	23.1	1.07	1.05	1.09	-0.4	-4.3	4.1
609-2A	2816 2831	14.1	1.1	26.0	1.03	1.01	1.05	1.0	-6.2	8.0
610-2A	2816 2831	8.5	0.9	19.6	1.05	1.02	1.07	3.8	-3.9	8.2
611-2A	2816 2831	29.8	2.5	54.1	1.04	1.01	1.10	3.4	-4.6	8.5
612-2A	2816 2831	30.6	25.0	37.9	1.02	1.01	1.04	5.4	2.5	8.4
613-2A	2816 2831	30.5	6.5	43.7	1.03	1.01	1.05	3.5	-0.6	8.0

RUN SUMMARY - SOLIDS ANALYTICAL DATA

CONCENTRATIONS IN SOLIDS, WT %

RUN NO.	ANALYTICAL POINT	CO2			SO2			SO3			CAO			ACID INSOLUBLES			SOLIDS IN SLURRY, WT %		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
614-2A	2816 2831	0.83	0.22	2.00	22.06	19.00	25.41	3.56	0.80	5.98	24.37	21.98	27.62	2.76	2.42	3.55	7.9	4.0	9.1
615-2A	2816 2831	0.55	0.15	1.65	19.49	15.56	24.22	5.22	1.57	8.78	21.97	18.54	25.29	3.03	2.48	3.42	8.1	7.5	8.6
616-2A	2816 2831	1.24	0.33	2.97	20.91	15.45	24.56	6.52	0.90	13.91	24.54	17.61	30.74	2.99	2.46	3.36	7.9	4.9	8.8
617-2A	2816 2831	1.16	0.71	1.70	22.59	19.18	25.46	3.50	1.68	6.78	24.95	22.62	27.79	5.10	3.11	6.01	14.3	8.1	15.5

RUN SUMMARY - SOLIDS ANALYTICAL DATA (CONTINUED)

RUN NO.	ANALYTICAL POINT	PERCENT SULFITE OXIDATION			STOICHIOMETRIC RATIO			PERCENT IONIC IMBALANCE		
		AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
614-2A	2816 2831	11.4	2.6	18.2	1.05	1.01	1.10	6.2	0.0	8.5
615-2A	2816 2831	17.7	5.3	27.6	1.03	1.01	1.09	2.6	-7.6	6.5
616-2A	2816 2831	19.6	4.3	33.8	1.07	1.01	1.17	0.4	-7.3	8.1
617-2A	2816 2831	11.0	5.6	22.0	1.07	1.04	1.11	5.0	0.0	8.4

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
2	TCA	583-2A	SLURRY TO TCA TOWER	04/15/76	2330			3640	580	82		15.9
				04/16/76	0330			3440	620	80		14.6
				04/16/76	0730			3440	500	84		15.3
				04/16/76	1130			3200	520	82		13.9
				04/16/76	1530			2560	400	83		11.2
				04/16/76	2330			2560	340	85		11.6
				04/17/76	0330			2400	420	81		10.2
				04/17/76	0730			2200	400	80		9.3
				04/17/76	1130							
				04/17/76	1530			2980	780	71		11.2
					1530			2980	780	71		11.2
				04/17/76	1930			2720	600	76		10.9
				04/17/76	2330			2720	740	70		10.1
				04/18/76	0730			3800	880	74		15.0
				04/18/76	1130			3300	1000	66		11.6
				04/18/76	1530			2400	480	79		9.9
				04/18/76	2330			3120	660	77		12.7
				04/19/76	0730			3120	560	79		13.1
				04/19/76	2330			3560	740	77		14.5
				04/20/76	2330			3560	600	81		15.3
			CLARIFIER UNDERFLOW-TCA	04/15/76	2330			3640	580	82		15.9
				04/16/76	2330			2560	340	85		11.6
				04/18/76	2330			3120	660	77		12.7
		583-2B	SLURRY TO TCA TOWER	04/22/76	0730			2920	280	89		13.8
				04/22/76	1130			2760	280	89		13.0
				04/22/76	1530			2640	100	96		13.4
				04/22/76	1930			3080	280	90		14.7
				04/22/76	2330			3200	800	72		12.3
				04/23/76	0330			3160	280	90		15.1
				04/23/76	0730			3040	320	98		14.2
				04/23/76	1130			3120	440	84		13.9
				04/23/76	1530			3160	380	87		14.5
				04/23/76	1930			2720	300	88		12.7
				04/23/76	2330			2480	520	77		10.1
				04/24/76	0330			2480	560	75		9.8
				04/24/76	0730			2520	340	85		11.4
				04/24/76	1130			2830	620	75		11.2
				04/24/76	1530			2840	680	73		11.1
				04/24/76	1930			3000	480	82		13.1
				04/24/76	2330			3080	600	78		12.8
				04/25/76	0330			2960	320	88		13.8
				04/25/76	0730			2960	260	90		14.2
				04/25/76	1130							
				04/25/76	1530			2730	320	87		12.7
				04/25/76	1930							

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	POIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
2	TCA	583-2B	SLURRY TO TCA TOWER	04/25/76	2330			2960	400	85		13.3
				04/26/76	0730			3160	280	90		15.1
				04/26/76	1130			3000	340	87		13.9
				04/26/76	1630			3200	340	88		15.0
				04/26/76	1930			3240	380	87		14.9
				04/26/76	2330			3280	360	88		15.3
				04/27/76	0730			3290	300	90		15.6
				04/27/76	0800							
				04/27/76	1130			3200	300	90		15.2
				04/27/76	1530			3440	380	88		16.0
				04/27/76	2330			2940	150	94		14.1
				04/28/76	0330			3000	300	89		14.1
				04/28/76	0730			2960	280	89		14.0
				04/28/76	1030			2800	400	84		12.5
				04/28/76	1530			2400	60	97		12.4
				04/28/76	2330			2200	160	92		10.7
				04/29/76	0730			2100	140	93		10.3
				04/29/76	1530			3400	420	86		15.5
				04/29/76	2330			3480	440	86		15.9
				04/30/76	0730			3600	500	85		16.1
				04/30/76	1530			3200	320	89		15.1
				04/30/76	2330			2520	240	89		11.9
				05/01/76	0730			3160	900	68		11.5
			CENTRIFUGE CAKE	04/22/76	0730			2920	280	89		13.8
				04/23/76	0730			3040	320	88		14.2
				04/24/76	0730			2520	340	85		11.4
				04/25/76	0730			2960	260	90		14.2
				04/27/76	0730			3280	300	90		15.6
				04/28/76	0730			2960	280	89		14.0
				04/30/76	1530			3200	320	89		15.1
		584-2A	SLURRY TO TCA TOWER	05/04/76	0730			2360	320	85		10.6
				05/04/76	1530			2600	400	84		12.5
				05/04/76	2330			3400	280	91		16.4
				05/05/76	0730			3720	100	97		19.1
				05/05/76	1530			2360	40	98		12.3
				05/05/76	2330			2760	60	98		14.3
				05/06/76	0730			3000	80	97		15.4
				05/07/76	0730			3160	60	98		16.4
				05/07/76	1530			3120	240	91		15.1
				05/07/76	2330			3100	90	97		15.9
				05/08/76	0730			3520	120	96		18.0
				05/08/76	1530			3160	80	97		16.3
				05/08/76	2330			2880	180	93		14.2
				05/09/76	0730			2960	300	89		13.9
				05/09/76	1530			2520	110	95		12.7

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
2	TCA	584-2A	SLURRY TO TCA TOWER	05/09/76	2330			3040	140	95		15.3
				05/10/76	0730			3240	120	96		16.5
				05/10/76	1300							
				05/10/76	1530			2680	80	97		13.7
				05/11/76	0730			3240	200	93		16.0
				05/11/76	1530			3280	150	94		16.3
				05/11/76	2330			3040	160	94		15.2
				05/12/76	0730			4000	400	89		18.8
				05/12/76	0845							
				05/12/76	1530			3600	280	91		17.4
				05/12/76	2330			3680	200	94		18.3
				05/13/76	0730			2200	100	95		11.1
				05/13/76	1300							
				05/13/76	1530			2080	140	93		10.2
				05/13/76	2330			2720	200	92		13.2
				05/14/76	0730			2840	140	95		14.2
			CLARIFIER UNDERFLOW-TCA	05/07/76	2330			3100	90	97		15.9
		585-2A	SLURRY TO TCA TOWER	05/14/76	1530			2800	440	83		16.7
				05/14/76	2330			2960	550	79		16.6
				05/15/76	0730			3280	560	81		18.8
				05/15/76	1530			3080	700	80		21.9
				05/15/76	2330			2600	260	89		16.3
				05/16/76	0730			2840	400	84		16.9
				05/16/76	1530			2760	180	93		18.1
				05/16/76	2330			2800	420	83		14.5
				05/17/76	0730			3160	360	87		19.5
				05/17/76	1530			2960	200	92		19.7
				05/17/76	2330			3040	230	90		19.3
				05/18/76	0730			3080	500	82		17.8
				05/18/76	1530			2600	440	81		14.9
				05/18/76	2330			2720	400	84		16.1
				05/19/76	0730			3040	380	86		18.5
				05/19/76	1530			2560	340	85		15.4
				05/19/76	2330			2400	180	92		15.5
				05/20/76	0730			3600	600	81		20.7
			CLARIFIER UNDERFLOW-TCA	05/14/76	2330			2960	550	79		16.6
				05/17/76	2330			3040	280	90		19.3
		586-2A	SLURRY TO TCA TOWER	05/20/76	1600			3960	1020	71		15.0
				05/20/76	2330			3700	460	85		16.9
				05/21/76	0730			2840	660	74		11.2
				05/21/76	1530			2600	380	84		11.5
				05/21/76	2330			2440	420	81		10.5
				05/22/76	0730			2400	540	75		9.5
				05/22/76	1530			2480	280	87		11.5
				05/22/76	2330			2520	440	81		10.8

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
2	TCA	586-2A	SLURRY TO TCA TOWER	05/23/76	0730			2560	560	76		10.3
				05/23/76	1530			3360	480	84		15.0
				05/23/76	2330			2520	460	80		10.6
				05/24/76	0730			2120	480	75		8.4
				05/24/76	1600							
				05/24/76	2330			3160	560	80		13.5
				05/25/76	0445			3620	800	75		14.5
			CLARIFIER UNDERFLOW-TCA	05/21/76	2330			2440	420	81		10.5
				05/24/76	2330			3160	560	80		13.5
		587-2A	SLURRY TO TCA TOWER	05/31/76	1530			2800	100	96		14.3
				05/31/76	2330			2480	60	97		12.8
				06/01/76	0730			2840	50	98		14.6
				06/01/76	1530			3160	120	96		16.0
				06/01/76	2330			2960	60	98		15.3
				06/02/76	0730			2840	60	98		14.7
				06/02/76	0800							
				06/02/76	1530			3160	60	98		16.4
				06/02/76	2330			2700	60	99		14.0
				06/03/76	0730			2680	60	98		13.9
				06/03/76	1530			3320	120	96		16.9
				06/03/76	2300			2400	100	95		12.1
				06/05/76	1530			3160	200	93		15.6
				06/05/76	2330			3000	120	96		15.2
				06/06/76	0730			3200	300	90		15.2
				06/06/76	1530			2800	120	95		14.1
				06/06/76	2330			3000	160	94		15.0
				06/07/76	0730			3320	540	82		14.4
				06/07/76	1530			2960	180	93		14.6
				06/07/76	2330			3500	320	90		16.7
				06/08/76	0730			3640	240	93		17.9
				06/08/76	1530			2760	160	94		13.7
				06/08/76	2330			3100	180	94		15.4
				06/09/76	0730			2720	360	85		12.3
				06/09/76	1530			2760	160	94		13.7
				06/09/76	2330			2800	220	91		13.5
				06/10/76	0730			3300	350	88		15.4
				06/10/76	1530			2920	160	94		14.5
				06/10/76	2330			2440	80	96		12.5
				06/11/76	0730			2760	360	86		12.5
				06/11/76	1530			3640	400	88		16.9
				06/11/76	2330			3600	280	91		17.4
				06/12/76	0730			3560	380	88		16.6
				06/12/76	1530			3520	280	91		16.9
				06/12/76	2330			2840	80	97		14.6
				06/13/76	0730			2960	80	97		15.2

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
2	TCA	587-2A	SLURRY TO TCA TOWER	06/13/76	1530			3360	200	93		16.6
				06/13/76	2330			3800	260	92		18.6
				06/14/76	0530			3520	360	89		16.5
			CLARIFIER UNDERFLOW-TCA	05/31/76	2330			2480	60	97		12.9
				06/07/76	2330			3500	320	90		16.7
				06/11/76	2330			3600	280	91		17.4
			CENTRIFUGE CAKE	06/07/76	1530			2960	180	93		14.6
				06/11/76	1530			3640	400	88		16.9
		588-2A	SLURRY TO TCA TOWER	06/17/76	0730			2400	100	95		9.3
				06/17/76	1530			2380	200	91		7.8
				06/17/76	2330			3080	120	96		10.7
				06/18/76	0730			3100	150	95		10.6
				06/18/76	1530			3320	240	92		11.1
				06/18/76	2330			2400	220	90		7.8
				06/19/76	0730			2800	180	93		9.4
				06/19/76	1530			1900	80	95		6.6
				06/19/76	2330			1840	170	90		6.0
				06/20/76	0730			2200	250	87		6.9
					0730			2200	250	87		6.9
				06/20/76	1530			2520	130	94		8.6
				06/20/76	2330			1780	60	96		6.2
			CENTRIFUGE CAKE	06/18/76	0730			3100	150	95		10.6
				06/19/76	0730			2800	180	93		9.4
		589-2A	SLURRY TO TCA TOWER	06/21/76	1530			2200	160	92		10.7
				06/21/76	2330			2600	140	94		13.0
				06/22/76	0730			2440	110	95		12.3
				06/23/76	1530			3320	200	93		16.4
				06/23/76	2330			3440	220	93		16.9
				06/24/76	0730			3500	240	92		17.1
				06/24/76	1530			4360	400	90		20.8
				06/24/76	2330			3600	220	93		17.8
				06/25/76	2330			2280	180	91		11.0
				06/26/76	0730			3600	380	88		16.8
				06/26/76	1530			3680	440	87		16.9
				06/26/76	2330			3200	320	89		15.1
				06/27/76	0730			4000	440	83		18.6
				06/27/76	1530			3240	320	89		15.3
				06/27/76	2330			3360	320	89		15.9
				06/28/76	0730			3480	320	90		16.6
				06/28/76	1530			3720	320	90		17.8
				06/28/76	2330			3120	200	93		15.4
				06/29/76	0730			3520	250	92		17.2
				06/29/76	1530			3440	300	90		16.5
				06/29/76	2330			3600	380	88		14.8
				06/30/76	0730			4600	600	83		17.7

GAS ANALYSES

SCR NO.	SYS- TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
2	TCA	589-2A	SLURRY TO TCA TOWER	06/30/76	1530			4240	640	83		18.7
				06/30/76	2330			2520	220	90		12.1
				07/01/76	0500			2400	220	90		11.4
			CENTRIFUGE CAKE	06/28/76	1530			3720	320	90		17.8
		601-2A	SLURRY TO TCA TOWER	07/02/76	0730			3200	460	84		14.3
				07/02/76	1530			2880	320	88		13.4
				07/04/76	0730			2600	200	91		12.6
				07/06/76	1530			3040	200	93		14.9
				07/06/76	2330			2560	80	97		13.1
				07/07/76	0730			2560	200	91		12.4
				07/07/76	1530			3120	260	91		15.0
				07/07/76	2330			2640	180	92		12.9
				07/08/76	0730			2880	150	94		14.3
				07/08/76	1530			3160	140	95		15.9
				07/08/76	2330			2640	40	98		13.8
				07/09/76	0730			2680	160	93		13.3
				07/09/76	1530			3120	240	91		15.1
				07/09/76	2330			2560	180	92		12.5
				07/10/76	0730			2520	240	89		11.3
				07/10/76	1530			3060	200	93		15.0
				07/10/76	2330			3000	300	89		14.1
				07/11/76	0730			3000	340	87		13.9
				07/11/76	1530			2880	360	86		13.1
				07/11/76	2330			2880	280	89		13.2
				07/12/76	0530			3000	380	86		13.7
			CENTRIFUGE CAKE	07/02/76	1530			2880	320	85		13.4
				07/06/76	1530			3040	200	93		14.9
				07/07/76	1530			3120	260	91		15.0
				07/08/76	1530			3160	140	95		15.9
				07/09/76	1530			3120	240	91		15.1
				07/10/76	1530			3060	200	93		15.0
				07/11/76	1530			2880	360	86		13.1
		602-2A	SLURRY TO TCA TOWER	07/12/76	2330			2840	320	87		13.2
				07/13/76	0730			3080	300	89		14.6
				07/13/76	1530			2840	280	89		13.4
				07/13/76	2330			3040	120	96		15.4
				07/14/76	0730			2680	340	87		13.3
				07/14/76	1330							
				07/14/76	1530			3160	370	87		14.6
				07/14/76	2330			2920	400	85		13.1
				07/15/76	0730			2880	340	87		13.3
				07/15/76	0800							
				07/15/76	1530			3040	440	84		13.5
				07/15/76	2330			2800	360	86		12.7
				07/16/76	0730			3200	400	86		14.6

GAS ANALYSES

SCR NO.	SYS- TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
2	TCA	602-2A	SLURRY TO TCA TOWER	07/16/76	1530			3320	380	87		15.4
				07/16/76	2330			3280	340	88		15.4
				07/17/76	0730			3480	320	90		16.6
				07/17/76	1530			3880	400	83		16.2
				07/17/76	2330			3640	360	89		17.2
				07/18/76	0730			3090	340	87		13.9
			CENTRIFUGE CAKE	07/13/76	1530			2840	280	89		13.4
				07/14/76	1530			3160	370	87		14.6
				07/15/76	1530			3040	440	84		13.5
				07/16/76	1530			3320	380	87		15.4
				07/17/76	1530			3880	400	82		18.2
		603-2A	SLURRY TO TCA TOWER	07/20/76	0730			2440	250	89		11.5
				07/20/76	1530			2420	340	84		10.7
				07/20/76	2330			2400	280	97		11.1
					2330			2400	280	87		11.1
				07/21/76	0730			2060	200	89		9.7
				07/21/76	1530			2720	420	83		11.9
				07/21/76	2330			4760	1160	73		18.4
				07/22/76	0730			3600	700	78		15.0
				07/22/76	1530			4800	1200	72		18.4
					1530			4800	1200	72		18.4
					1530			4800	1200	72		19.4
				07/22/76	2330			4200	760	80		17.8
				07/23/76	0730			3280	400	86		15.0
				07/23/76	1530			3090	300	97		14.6
				07/23/76	2330			3320	380	87		15.4
				07/24/76	0730			3400	420	85		15.5
				07/24/76	1530			2650	220	91		12.5
				07/24/76	2330			2690	240	90		12.8
				07/25/76	0730			2640	140	94		13.2
				07/25/76	1530			2560	180	92		12.5
				07/25/76	2330			3080	300	99		14.6
				07/26/76	0730			3360	350	88		15.7
				07/26/76	1530			4200	800	79		17.6
			CENTRIFUGE CAKE	07/20/76	1530			2400	340	84		10.7
				07/21/76	1530			2720	420	83		11.9
				07/22/76	1530			4800	1200	72		18.4
				07/23/76	1530			3080	300	89		14.6
				07/24/76	1530			2600	220	91		12.5
				07/25/76	1530			2560	180	92		12.5
				07/26/76	1530			4200	800	79		17.6
		604-2A	SLURRY TO TCA TOWER	07/28/76	2330			4100	1140	69		20.0
				07/29/76	0730			4420	1400	65		20.3
				07/29/76	1530							
				07/29/76	2330			3400	920	70		16.8

GAS ANALYSES

SCR NO.	SYS- TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
2	TCA	604-2A	SLURRY TO TCA TOWER	07/30/76	0730			3600	980	73		17.8
				07/30/76	1530			3520	960	73		17.3
				07/30/76	2330			3540	950	73		17.6
				07/31/76	0730			3400	900	71		17.0
				07/31/76	1530			3440	900	71		17.2
				07/31/76	2330			3240	800	75		16.6
				08/01/76	0730			3200	900	72		16.3
				08/01/76	1530			3240	840	71		16.3
				08/01/76	2330			3120	760	75		16.1
				08/02/76	0730		128	3040	720	74		15.8
				08/02/76	1530		128	3200	740	74	6.2	16.8
				08/02/76	2330		113	3360	750	75	6.5	17.9
				08/03/76	0730		144	3240	700	76	7.0	17.4
				08/03/76	1530		143	2800	540	79	6.0	15.6
				08/03/76	2330		143	3680	900	73	6.4	18.9
				08/04/76	0530		144	3680	900	73		18.9
			CENTRIFUGE CAKE	07/29/76	1537							
				07/30/76	1530							
				08/02/76	1530		128	3200	740	74	6.2	16.8
				08/03/76	1530		143	2800	540	79	6.0	15.6
		605-2A	SLURRY TO TCA TOWER	08/05/76	0330		145	3400	600	80		9.3
				08/06/76	0730		136	3320	600	80	6.0	9.6
				08/06/76	1530		139	3300	750	77	6.2	11.1
				08/06/76	2330		140	3640	720	78	6.0	10.3
				08/07/76	0730		128	3520	700	78	6.0	9.9
				08/07/76	1530		140	3340	620	79	5.3	9.6
				08/07/76	2330		137	3200	480	83	5.6	9.7
				08/08/76	0730		146	3000	440	84	5.5	9.1
				08/08/76	1530		149	3120	510	82	5.2	9.2
				08/08/76	2330		145	3400	600	80	5.8	9.9
				08/09/76	0730		144	3200	500	83	6.3	9.6
				08/09/76	1530		143	3720	750	77	6.5	10.3
				08/09/76	2330		144	3920	800	77	6.4	11.0
				08/10/76	0730		145	4000	880	76	6.2	10.9
				08/10/76	1530		144	3400	680	78	6.5	9.5
				08/10/76	2330		148	3360	690	80	6.5	9.8
				08/11/76	0730		148	3360	640	79	5.2	9.6
				08/11/76	1530		149	3860	860	75	6.2	10.6
				08/11/76	2330		144	3880	800	77	6.4	10.8
				08/12/76	0730		143	3960	860	76		10.9
				08/12/76	1930		146	3920	1000	72	5.2	10.2
				08/12/76	2330		145	3960	740	79	5.5	11.4
				08/13/76	0730		148	3840	680	80	6.7	11.2
			CENTRIFUGE CAKE	08/06/76	1530		139	3900	750	79	6.2	11.1
				08/07/76	1530		140	3340	620	79	5.3	9.6

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	FOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
2	TCA	605-2A	CENTRIFUGE CAKE	08/08/76	1530		148	3120	510	82	5.2	9.2
				08/09/76	1530		143	3720	780	77	5.5	10.3
				08/10/76	1530		144	3400	680	78	6.5	9.6
				08/11/76	1530		149	3850	860	75	6.2	10.6
		606-2A	SLURRY TO TCA TOWER	08/13/76	1530		148	3280	620	72	6.2	15.7
				08/13/76	2330		148	3240	900	73	8.0	16.6
				08/14/76	0730		144	3440	960	69	7.7	16.8
				08/14/76	1530		149	3440	920	70	7.5	17.1
				08/14/76	2330		145	3400	880	71	8.0	17.1
				08/15/76	0730		143	3400	800	74	7.2	17.8
				08/15/76	1530		146	3840	1080	69	6.8	18.7
				08/15/76	2330		142	4000	1140	68	7.5	19.3
				08/16/76	0730		145	3720	940	72	6.5	18.9
				08/16/76	1530		146	3640	720	78	4.4	20.1
				08/16/76	2330		141	3360	660	78	5.0	18.6
				08/17/76	0730		143	3200	680	76	6.3	17.3
				08/17/76	1530		150	2480	360	84	5.8	14.7
				08/17/76	2330		110	3000	620	77	5.2	16.3
				08/18/76	0730		142	3280	680	77	8.5	17.8
				08/18/76	1345			2880	450	83		16.5
			CENTRIFUGE CAKE	08/13/76	1530		148	3250	820	72	6.2	16.7
				08/14/76	1530		149	3440	920	70	7.5	17.1
				08/15/76	1530		146	3840	1080	69	6.8	18.7
				08/16/76	1530		146	3640	720	78	4.4	20.1
				08/17/76	1530		150	2480	360	84	5.8	14.7
				08/18/76	1345			2880	450	83		16.8
		607-2A	SLURRY TO TCA TOWER	08/19/76	1600	X	149	3000	460	83	6.8	17.6
				08/19/76	2330	X	136	3440	140	95	6.2	23.2
				08/20/76	0730	X	138	3700	200	94	9.8	24.6
				08/20/76	1530		143	3400	260	92	5.2	22.0
				08/20/76	2330		148	3320	120	96	5.5	22.5
				08/21/76	0730		145	3360	280	91	6.5	21.5
				08/21/76	1530		146	3280	110	96	7.2	22.3
				08/21/76	2330		145	3120	220	92	6.0	20.3
				08/22/76	0730		135	3160	550	81	6.8	18.0
					0730		135	3160	550	81	6.8	18.0
				08/22/76	1530		146	3320	320	89		21.0
					1530		146	3320	320	89		21.0
				08/22/76	2330		146	3120	480	83		18.3
				08/23/76	0730		148	2720	400	84		16.1
				08/23/76	1530		145	2400	320	85	6.0	14.4
				08/23/76	2330		142	3280	660	79	4.5	18.0
					2330		142	3280	660	78	4.5	18.0
				08/24/76	0730		144	3320	540	82	5.2	19.2
					0730		144	3320	540	82	5.2	19.2

GAS ANALYSES

SCP NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
2	TCA	607-2A	SLURRY TO TCA TOWER	08/24/76	1530		144	3040	420	85	4.5	18.2
				08/24/76	2330		103	2960	380	86	7.7	17.9
				08/25/76	0530			3360	580	81	7.2	19.2
				08/30/76	1530		146	3200	520	82	6.0	18.5
				08/30/76	2330		135	3200	450	84	6.2	19.1
				08/31/76	0730		143	3360	580	81	6.5	19.2
					0730		143	3360	580	81	6.5	19.2
				08/31/76	1530		144	3600	580	82	5.2	20.9
					1530		144	3600	580	82	5.2	20.9
				08/31/76	2330		148	3840	760	78	5.5	21.5
				09/01/76	0730		146	3600	760	78	5.8	20.9
				09/01/76	1530		143	3600	640	80	5.0	20.4
				09/01/76	2330		148	3200	480	83	5.4	18.8
				09/02/76	0730		147	3800	760	78	6.0	20.9
					0730		147	3800	760	78	6.0	20.9
				09/02/76	1530		145	3320	360	88	5.0	20.6
					1530		145	3320	360	88	5.0	20.6
			CENTRIFUGE CAKE	08/19/76	1600	X	149	3000	460	83	6.8	17.6
					1600	X	148	3000	460	83	6.8	17.6
					1600	X	148	3000	460	83	6.8	17.6
				08/20/76	1530		143	3400	260	92	6.2	22.0
				08/21/76	1530		146	3280	110	96	7.2	22.3
				08/22/76	1530		146	3320	320	89		21.0
				08/23/76	1530		145	2400	320	85	6.0	14.4
				08/24/76	1530		144	3040	420	85	4.5	18.2
				08/30/76	1530		146	3200	520	82	6.0	18.5
			SLURRY AT TCA OUTLET	08/31/76	1530		144	3600	580	82	5.2	20.9
				09/01/76	1530		143	3600	640	80	5.0	20.4
				09/02/76	1530		145	3320	360	88	5.0	20.6
		608-2A	SLURRY TO TCA TOWER	09/03/76	1530		144	3840	720	79	7.6	21.5
				09/03/76	2330		142	4040	860	76	7.5	21.2
				09/04/76	0730		144	3720	700	79	5.2	20.5
				09/04/76	1530		144	3660	340	90	5.0	23.2
				09/04/76	2330		141	3880	780	78	5.8	21.3
				09/05/76	0730		145	3840	700	80	5.5	21.6
				09/05/76	1530		54	3560	500	84	5.5	21.2
				09/05/76	2330		143	3480	520	83	5.6	20.5
				09/06/76	0730		119	3340	700	80	5.9	21.6
				09/06/76	1530		143	3560	500	84	5.5	21.2
				09/08/76	0730							
			SLURRY AT TCA OUTLET	09/03/76	1530		144	3840	720	79	7.6	21.5
				09/04/76	1530		144	3660	340	90	5.0	23.2
				09/05/76	1530		54	3560	500	84	5.5	21.2
				09/06/76	1530		143	3560	500	84	5.5	21.2
		608-2B	SLURRY TO TCA TOWER	09/07/76	0330		145	3640	520	90	5.2	23.2

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GAS ANALYSES

                                                                                POTL                                    MAKE
 SCR  SYS-  RUN                                                         GAS/  LOAD    SO2    SO2   SO2      O2      PER
 NO.  TEM   NO.     SAMPLE NAME                   DATE      TIME  TIME  MEGA    IN     OUT   REM      IN      PASS
                                                                        FLAG  WATT    PPM    PPM    %        %     MMOL/L
 ---  ----  ------  ------------------------   --------   ----  ----  ----    ----   ----   ---    ----   ------
  2   TCA   608-2B  SLURRY TO TCA TOWER        09/07/76   0730              144    3540    300    91             23.4
                                               09/07/76   1130
                                               09/07/76   1530              148    3640    180    95    5.5      24.3
                                               09/07/76   1330
                                               09/07/76   2330              137    3920    100    97    6.0      26.9
                                               09/08/76   1530              113    3320    220    93    5.5      21.7
                                               09/08/76   2330              105    3040     70    97    5.0      20.9
                                               09/09/76   0730              107    3160     80    97    4.7      21.7
                                               09/09/76   1600              108    3140    100    96    5.2      21.4
                                               09/09/76   2330              100    2400    160    93             15.7
                                               09/10/76   0730              100    2200    220    89    7.2      14.4
                                               09/10/76   1530              150    3000    260    90             19.2
                                               09/10/76   2330              139    3040     60    98             21.0
                                               09/11/76   0730              146    3200     80    97             22.0
                                               09/11/76   1530              148    3360     80    97    8.6      23.1
                                               09/11/76   2330              117    3080     30    99    9.0      21.5
                                               09/12/76   0730              145    3560     60    99    8.0      24.5
                                               09/12/76   1530              148    3320     80    97    8.2      22.8
                                               09/12/76   2330              141    3040     60    98    8.5      21.0
                                               09/13/76   0600              142    3280     60    98             22.7
                    SLURRY AT TCA OUTLET       09/08/76   1530              113    3320    220    93    5.5      21.7
                                               09/09/76   1600              108    3140    100    96    5.2      21.4
                                               09/10/76   1530              150    3000    260    96             19.2
                                               09/11/76   1530              148    3360     80    97    8.6      23.1
                                               09/12/76   1530              148    3320     80    97    8.2      22.8
            609-2A  SLURRY TO TCA TOWER        09/13/76   1530    X         163    3320    150    95    7.2      22.2
                                               09/13/76   2330    X         146    3320    120    96    7.5      22.5
                                               09/14/76   0730    X         146    3520    150    95    7.0      23.7
                                               09/14/76   1530    X         142    3200    280    90    7.4      20.4
                                                          1530    X         142    3200    280    90    7.4      20.4
                                               09/14/76   2330    X         112    3080    220    92   10.0      20.0
                                               09/15/76   0730    X         146    3240    650    78    8.5      17.8
                                               09/15/76   1345    X
                                               09/15/76   1600    X         143    3160    560    82    9.2      17.9
                                               09/15/76   2330    X         143    3000    740    73             15.4
                                               09/16/76   0730    X         144    2780    520    79    5.5      15.6
                                               09/16/76   1530    X         145    2860    500    81    5.8      16.4
                                               09/16/76   2330    X         143    3080    700    75   11.2      16.3
                                                          2330    X         143    3080    700    75   11.2      16.3
                                               09/17/76   0730    X         147    3320    690    77             18.0
                                               09/17/76   1530    X         147    3200    680    76    5.8      17.3
                                               09/17/76   2330    X         147    3160    720    75    7.2      16.7
                                               09/18/76   0730              144    3240    730    75    5.3      17.2
                                               09/18/76   1530              145    2920    720    73    6.5      15.0
                                               09/18/76   2330              147    2260    600    73    5.2      14.6
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GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
2	TCA	609-2A	SLURRY TO TCA TOWER	09/19/76	0730		147	3440	920	73	5.5	17.1
				09/19/76	1530		148	3560	920	71	6.0	17.9
				09/19/76	2330		144	2830	520	79	5.6	15.7
				09/20/76	0730		149	2600	400	83	6.3	15.2
				09/20/76	1530		146	2480	500	78	7.0	13.6
				09/20/76	2330		115	2630	740	69	7.2	13.1
				09/21/76	0730		149	3120	800	72	7.0	15.5
				09/21/76	1530		149	2920	740	72	6.5	14.8
				09/21/76	2330		116	2960	750	72	6.5	15.0
				09/22/76	0730		148	3340	800	73	6.5	17.3
				09/22/76	1530		147	3320	660	78	6.5	18.3
				09/22/76	2330		131	3280	720	76	7.3	17.5
				09/23/76	0730		149	2960	600	77	7.8	16.2
				09/23/76	1530		149	3000	660	76	6.7	16.0
				09/23/76	2330		124	3860	880	75	7.0	20.4
				09/24/76	0500		120	3600	900	72		18.4
			SLURRY AT TCA OUTLET	09/13/76	1530	Y	163	3320	160	95	7.2	22.2
				09/14/76	1530	X	142	3200	280	92	7.4	20.4
				09/15/76	1600	Y	143	3160	560	80	9.2	17.9
				09/16/76	1530	Y	145	2880	500	81	6.8	16.4
				09/17/76	1530	Y	147	3200	680	76	5.8	17.3
				09/18/76	1530		145	2920	720	73	6.5	15.0
				09/19/76	1530		148	3560	920	71	6.0	17.9
				09/20/76	1530		146	2480	500	78	7.0	13.6
				09/21/76	1530		149	2920	740	72	6.5	14.8
				09/22/76	1530		147	3320	660	78	6.5	18.3
				09/23/76	1530		149	3000	660	76	6.7	16.0
		610-2A	SLURRY TO TCA TOWER	09/24/76	1530		144	3720	660	80	7.0	21.1
				09/24/76	2330		143	3300	450	85	7.5	19.8
				09/25/76	0730		143	3160	400	86	7.4	19.2
				09/25/76	1530		143	3160	450	84	6.5	18.7
				09/25/76	2330		139	3240	500	83	7.0	19.0
				09/26/76	0730		137	3400	400	87	7.2	20.9
				09/26/76	1530		146	3320	420	86	6.5	20.2
				09/26/76	2330		145	3320	420	86	6.5	20.2
				09/27/76	0730		133	3440	620	80	5.7	19.4
				09/27/76	1530		144	3320	320	89	4.9	21.0
				09/28/76	2330		134	3040	360	87	6.5	18.7
				09/29/76	0730		146	3200	320	89	6.3	20.1
				09/29/76	1530		145	2760	300	88	6.0	17.2
				09/29/76	2330		136	2760	300	88	6.0	17.2
				09/30/76	0730		145	2840	280	89	6.6	17.9
				09/30/76	1530		145	3160	340	88	6.5	19.7
				09/30/76	2330		135	2800	180	93		18.4
				10/01/76	0730		145	3040	340	88	7.3	19.8

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO_2 IN PPM	SO_2 OUT PPM	SO_2 REM %	O_2 IN %	MAKE PER PASS MMOL/L
2	TCA	610-2A	SLURRY TO TCA TOWER	10/01/76	1530		147	3000	460	83	9.0	17.6
				10/01/76	2330		141	2880	360	86	9.2	17.5
				10/02/76	0730		146	3000	460	83	9.0	17.6
				10/02/76	1530		145	2920	460	83	7.0	17.0
				10/02/76	2330		140	2900	560	79		15.4
				10/03/76	0730		141	2600	560	78	6.5	15.4
				10/03/76	1530		140	2300	380	82	6.3	13.3
				10/03/76	2330		120	2240	360	92	6.4	13.0
				10/04/76	0500		115	2920	540	79		16.4
				10/04/76	1530		144	2520	380	83	6.4	14.8
				10/04/76	2330		144	3280	540	82	6.5	18.9
				10/05/76	0730		143	3360	620	80	8.2	18.9
				10/05/76	1530		145	2720	420	83	9.0	15.9
				10/05/76	2330		141	2520	400	82	6.6	14.7
				10/06/76	0730		144	3040	540	80	9.0	17.2
				10/06/76	1530		147	2940	500	81	9.0	16.9
				10/06/76	2330		124	2720	360	85	9.5	16.4
				10/07/76	0730		148	2600	360	94	8.5	15.4
			CENTRIFUGE CAKE	09/27/76	1530		144	3320	320	89	4.9	21.0
				09/29/76	1530		145	2760	300	98	6.0	17.2
			SLURRY AT TCA OUTLET	09/24/76	1530		144	3720	660	80	7.0	21.1
				09/25/76	1530		148	3160	460	84	5.5	18.7
				09/25/76	2330		145	3320	420	86	6.5	20.2
				09/27/76	1530		144	3320	320	89	4.9	21.0
				09/29/76	1530		145	2760	300	98	5.0	17.2
				09/30/76	1530		145	3160	340	88	5.5	19.7
				10/01/76	1530		147	3000	460	83	9.0	17.6
				10/02/76	1530		145	2920	460	83	7.0	17.0
				10/03/76	1530		140	2300	380	82	6.3	13.3
				10/04/76	1530		144	2520	360	83	6.4	14.8
				10/05/76	1014							
				10/06/76	1530		147	2340	500	81	9.0	16.9
		611-2A	SLURRY TO TCA TOWER	10/07/76	1530		148	2400	340	84	8.0	14.3
				10/07/76	2330		145	2960	500	81	5.5	17.0
				10/08/76	0730		144	3080	600	78	5.5	17.1
				10/08/76	1530		146	2800	480	81	6.6	16.0
				10/08/76	2330		144	2960	520	80	6.2	16.8
				10/09/76	0730		145	2920	500	81	5.6	15.7
				10/09/76	1530		124	3280	700	76	5.7	17.7
				10/09/76	2330		115	2760	480	81	6.2	15.7
				10/10/76	0730		145	3120	620	78	6.5	17.2
				10/10/76	1530		145	3520	740	77	5.2	19.1
				10/10/76	2330		141	2640	360	85	7.0	15.8
				10/11/76	0730		100	2920	460	83	7.7	17.0
				10/11/76	1530		107	2520	400	82	6.7	14.7

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
2	TCA	611-2A	SLURRY TO TCA TOWER	10/11/76	2330		107	2640	420	82	5.2	15.4
					2330		107	2640	420	82	5.2	15.4
				10/12/76	0530		146	3160	540	81	6.2	18.1
			SLURRY AT TCA OUTLET	10/07/76	1530		148	2400	340	84	8.0	14.3
				10/08/76	1530		146	2800	480	81	6.6	16.0
				10/09/76	1530		124	3280	700	76	5.7	17.7
				10/10/76	1530		145	3520	740	77	5.2	19.1
				10/11/76	1530		107	2520	400	82	6.7	14.7
		612-2A	SLURRY TO TCA TOWER	10/12/76	1530		146	2920	480	82	6.7	16.9
				10/12/76	2330		143	3120	660	77	6.2	16.9
				10/13/76	0730		145	2800	500	80	5.3	15.3
				10/13/76	1530		146	3040	520	81	5.8	17.4
				10/13/76	2330		146	2960	590	78	6.2	16.4
				10/14/76	0730		148	3000	500	81	6.5	17.3
				10/14/76	1530		146	3120	560	80	6.4	17.7
				10/14/76	2330		143	2960	480	82	6.5	17.2
				10/15/76	0730		146	3040	600	75	5.0	15.8
				10/15/76	1530		150	2850	440	83	5.8	16.9
				10/15/76	2330		147	2830	460	82	5.1	16.7
				10/16/76	0730		145	3100	530	81	6.0	17.7
				10/16/76	1530		149	3040	460	83	6.1	17.9
				10/16/76	2330		141	3200	580	80	5.5	18.1
				10/17/76	0730		148	3360	600	80	6.2	19.0
				10/17/76	1530		149	3200	540	81	7.5	18.4
				10/17/76	2330		150	3230	520	82	6.1	19.1
				10/18/76	0730		145	3760	700	79	7.5	21.1
			SLURRY AT TCA OUTLET	10/12/76	1530		146	2920	480	82	6.7	16.9
				10/13/76	1530		146	3040	520	81	5.8	17.4
				10/14/76	1530		146	3120	560	80	6.4	17.7
				10/15/76	1530		150	2880	440	83	6.8	16.9
				10/16/76	1530		149	3040	460	85	6.1	17.9
				10/17/76	1530		149	3200	540	81	7.5	18.4
		613-2A	SLURRY TO TCA TOWER	10/18/76	1930		147	3720	640	81	8.8	16.0
				10/18/76	2330		147	3560	620	81	8.2	15.2
				10/19/76	0730		146	3400	590	81	10.3	14.6
				10/19/76	1530		147	3200	470	83	9.5	14.1
				10/19/76	2330		137	3400	540	82	8.5	14.8
				10/20/76	0730		145	3280	400	86	9.0	15.0
				10/20/76	1530		146	2080	180	90	6.1	10.0
				10/20/76	2330		143	2960	380	86	6.7	13.5
				10/21/76	0730		136	3920	780	78	6.5	16.2
			SLURRY AT TCA OUTLET	10/18/76	1930		147	3720	640	81	8.8	16.0
				10/19/76	1530		147	3200	480	83	9.5	14.1
				10/20/76	1530		146	2080	180	90	6.1	10.0
		614-2A	SLURRY TO TCA TOWER	10/22/76	1530	7	146	3560	240	93	9.0	23.3

GAS ANALYSES

SCR NO.	SYS- TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
2	TCA	614-2A	SLURRY TO TCA TOWER	10/22/76	2330	Z	146	3560	760	76	6.8	19.2
				10/23/76	0730	Z	114	3600	620	77	7.8	16.3
					0730	Z	114	3000	620	77	7.8	16.3
				10/23/76	1530		144	3320	780	74	7.2	17.3
				10/23/76	2330		149	3160	730	74	7.5	16.6
				10/24/76	0730		140	3200	900	72	7.6	16.3
				10/24/76	1530		149	3080	760	73	5.2	15.8
				10/24/76	2330		149	3340	760	75	5.5	17.6
				10/25/76	0730		149	3900	960	75		20.1
				10/25/76	1530		145	3360	480	84	6.2	20.0
				10/25/76	2330		149	3400	680	73	5.0	19.7
				10/26/76	0730		148	4040	960	74	5.5	21.0
				10/26/76	1530			3800	900	74	6.6	19.8
					1530			3800	900	74	6.6	19.8
				10/26/76	2330			3680	740	78	6.0	20.2
				10/27/76	0730		149	3800	760	77	6.0	20.7
				10/27/76	1530		148	3520	760	76	5.5	18.9
				10/27/76	2330		125	4240	1080	72		21.5
				10/28/76	0730		120	4160	960	74	8.8	21.9
		615-2A	SLURRY TO TCA TOWER	10/28/76	1530		138	3960	680	81	7.8	17.6
				10/28/76	2330		150	3560	500	84	7.3	15.9
				10/29/76	0730		147	3400	400	87	6.3	15.7
				10/29/76	1530		150	3200	380	87	6.5	14.7
				10/29/76	2330		150	3000	340	87	6.2	13.9
				10/30/76	0730		150	2920	320	88	6.8	13.6
				10/30/76	1530		138	2880	260	90	6.5	13.7
				10/30/76	2330		150	2680	220	91	5.7	12.9
				11/01/76	1530		149	2500	240	89	12.5	11.8
				11/01/76	2330		150	3040	320	88	9.6	14.2
				11/02/76	0730		156	3080	300	89	7.2	14.6
				11/02/76	1530		149	3000	360	87	6.5	13.6
				11/02/76	2330		132	3560	500	84	7.2	15.9
				11/03/76	0730		94	3200	440	85	7.1	14.4
			SLURRY AT TCA OUTLET	10/28/76	1730		135					
				10/28/76	2330		150	3560	500	84	7.3	15.9
				10/29/76	0730		147	3400	400	87	6.3	15.7
				10/29/76	1530		150	3200	380	87	6.5	14.7
				10/29/76	2330		150	3000	340	87	6.2	13.9
				10/30/76	0730		150	2920	320	88	6.8	13.6
				10/30/76	1530		138	2880	260	90	6.5	13.7
				10/30/76	2330		150	2680	220	91	5.7	12.9
				11/01/76	1530		149	2500	240	89	12.5	11.8
				11/01/76	2330		150	3040	320	88	9.6	14.2
				11/02/76	0730		156	3080	300	89	7.2	14.6
				11/02/76	1530		149	3000	360	87	6.5	13.8

GAS ANALYSES

SCR NO.	SYS- TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
2	TCA	615-2A	SLURRY AT TCA OUTLET	11/02/76	2330		132	3560	500	84	7.2	15.9
				11/03/76	0730		94	3200	440	85	7.1	14.4
		616-2A	SLURRY TO TCA TOWER	11/05/76	2330	Z	156	3040	720	74	5.4	11.9
				11/06/76	0730	Z	149	3280	860	71	5.0	12.3
				11/06/76	1530		142	2800	600	76	5.5	11.3
					1530		142	2800	600	76	5.5	11.3
				11/06/76	2330		140	3200	740	74	7.2	12.6
				11/07/76	0730		80	3360	880	71		12.6
				11/07/76	1530		110	3800	1100	68	10.5	13.7
				11/07/76	2330		153	2680	520	78	6.6	11.1
				11/08/76	0730		149	3080	700	75	6.5	12.2
				11/08/76	1530		151	3440	920	76	7.2	12.9
				11/08/76	2330		155	3600	900	72	6.2	13.6
				11/09/76	0730		146	3400	840	73	5.0	13.1
				11/09/76	1530		153	2900	720	72	5.4	11.1
				11/09/76	2330		156	2760	760	69	5.7	10.2
				11/10/76	0730		152	2920	720	73	5.8	11.2
				11/10/76	1530		155	2760	840	66	5.6	9.7
				11/10/76	2330		154	3800	1260	63		12.7
				11/11/76	0730		149	3680	1200	64	6.0	12.4
				11/11/76	1730	Z	155	3840	660	81		16.5
				11/11/76	2330	Z	142	3720	620	81	5.3	16.1
				11/12/76	0730	Z	152	3680	720	79	5.9	15.3
				11/12/76	1530	Z	155	3400	440	86	6.0	15.4
				11/12/76	2330	Z	152	3720	600	82	8.4	16.2
				11/13/76	0730	Z	152	4000	740	79	6.5	16.8
			SLURRY AT TCA OUTLET	11/05/76	2330	Z	156	3040	720	74	5.4	11.9
				11/06/76	0730	Z	149	3280	860	71	5.0	12.3
				11/06/76	1530		142	2800	600	76	5.5	11.3
				11/06/76	2330		140	3200	740	74	7.2	12.6
				11/07/76	0730		80	3360	880	71		12.6
				11/07/76	1530		110	3800	1100	68	10.5	13.7
				11/07/76	2330		153	2680	520	78	6.6	11.1
				11/08/76	0730		149	3080	700	75	6.5	12.2
				11/08/76	1530		151	3440	920	76	7.2	12.9
				11/08/76	2330		155	3600	900	72	6.2	13.6
				11/09/76	0730		146	3400	840	73	5.0	13.1
				11/09/76	1530		153	2900	720	72	5.4	11.1
				11/09/76	2330		156	2760	760	69	5.7	10.2
				11/10/76	0730		152	2920	720	73	5.8	11.2
				11/10/76	1530		155	2760	840	66	5.6	9.7
				11/10/76	2330		154	3800	1260	63		12.7
				11/11/76	0730		149	3680	1200	64	6.0	12.4
				11/11/76	1730	Z	155	3840	660	81		16.5
				11/11/76	2330	Z	142	3720	620	81	5.3	16.1

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
2	TCA	616-2A	SLURRY AT TCA OUTLET	11/12/76	0730	Z	152	3680	720	78	5.9	15.3
				11/12/76	1530	Z	155	3400	440	85	6.0	15.4
				11/12/76	2330	Z	152	3720	600	82	2.4	16.2
				11/13/76	0730	Z	152	4000	740	79	6.5	16.8
		617-2A	SLURRY TO TCA TOWER	11/15/76	1930		157	3600	700	78	5.5	15.0
				11/15/76	2330		153	3320	580	81	9.1	14.2
				11/16/76	0730		155	3280	720	76	7.2	13.1
				11/16/76	1530		153	3320	600	85	7.0	14.1
				11/16/76	2330		155	3280	620	79	6.5	13.7
				11/17/76	0730		154	3120	520	81	7.1	13.5
				11/17/76	1530		154	3080	540	81	7.0	13.1
				11/17/76	2330		155	2680	420	83	7.3	11.7
				11/18/76	0730			2400	300	86	7.2	11.0
				11/18/76	1730			2200	260	87	4.5	10.1
				11/18/76	2330			2960	480	82	5.2	12.9
				11/19/76	0930		148	3280	540	78		13.6
				11/19/76	1530		124	3200	600	79	6.4	13.4
				11/19/76	2330		101	3200	720	75	7.0	12.7
				11/20/76	0730		141	3480	740	76	6.8	14.1
				11/20/76	1530		148	3160	640	78	5.8	13.0
				11/20/76	2330		152	3160	640	78	6.5	13.0
				11/21/76	0730		148	3260	700	76	6.1	13.2
				11/21/76	1530		148	3440	780	75	6.4	13.6
				11/21/76	2330		151	3000	580	79	6.5	12.5
				11/22/76	0730		146	2840	540	79	6.2	11.9
			SLURRY AT TCA OUTLET	11/15/76	1930		157	3600	700	78	5.5	15.0
				11/15/76	2330		153	3320	580	81	9.1	14.2
					2330		153	3320	580	81	9.1	14.2
					2330		153	3320	580	81	9.1	14.2
				11/16/76	0730		155	3280	720	76	7.2	13.1
				11/16/76	1530		153	3320	600	80	7.0	14.1
				11/16/76	2330		155	3280	620	79	6.5	13.7
				11/17/76	0730		154	3120	520	81	7.1	13.5
				11/17/76	1530		154	3020	540	81	7.0	13.1
				11/17/76	2330		155	2680	420	83	7.3	11.7
				11/18/76	0730			2400	300	86	7.2	11.0
				11/18/76	1730			2200	260	87	4.5	10.1
				11/18/76	2330			2960	490	82	5.2	12.9
				11/19/76	0930		148	3280	540	78		13.6
				11/19/76	1530		124	3200	600	79	6.4	13.4
				11/19/76	2330		101	3200	720	75	7.0	12.7
				11/20/76	0730		141	3480	740	76	6.8	14.1
				11/20/76	1530		148	3160	640	78	5.9	13.0
				11/20/76	2330		152	3160	640	78	6.5	13.0
				11/21/76	0730		148	3260	700	76	6.1	13.2

GAS ANALYSES

SCR NO.	SYS-TEM	RUN NO.	SAMPLE NAME	DATE	TIME	GAS/ TIME FLAG	BOIL LOAD MEGA WATT	SO2 IN PPM	SO2 OUT PPM	SO2 REM %	O2 IN %	MAKE PER PASS MMOL/L
2	TCA	617-2A	SLURRY AT TCA OUTLET	11/21/76	1530		148	3440	790	75	6.4	13.6
				11/21/76	2330		151	3000	590	79	6.5	12.5
				11/22/76	0730		146	2840	540	79	6.2	11.9

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
583-24	2816	04/15/76	2330	X	5.87	1380	875	74	203	45	3003	3057	2304	7884	122	50	13.8
		04/16/76	0330		5.40												
		04/16/76	0730		5.57	2092	3309	84	218	180	7542	7758	7800	21225	187	51	1.1
		04/16/76	1130		5.58												
		04/16/76	1530		5.62												
		04/16/76	2330		5.52	2260	2799	83	227	589	3815	4521	8363	19635	117	50	2.4
		04/17/76	0330		5.52												
		04/17/76	0730		5.58												
		04/17/76	1130		5.27											50	
		04/17/76	1530		5.37											52	
					5.77	1908	2619	90	70	904	4335	5920	7622	13348	133	50	-6.9
		04/17/76	1930		5.37												
		04/17/76	2330		5.33												
		04/18/76	0730	MG	5.12	2012	2249	83	112	226	5979	6250	7800	18461	182	50	-19.9
		04/18/76	1130		5.27												
		04/18/76	1530		5.37												
		04/18/76	2330	CL	5.41	1640	2019	90	114	271	4519	4844	5913	15590	131	50	-15.6
		04/19/76	0730		5.48	1680	2079	103	95	180	5279	5495	5950	15266	150	50	-6.7
		04/19/76	2330	MG	5.54	1570	1704	97	92	90	4262	4372	5672	13487	131	50	-11.5
		04/20/76	2330		5.75	1228	2379	91	104	226	5440	5711	5318	14796	111	51	-2.0
	2818	04/15/76	2330		6.73												
		04/16/76	2330		6.40												
		04/18/76	2330		8.02												
583-25	2816	04/22/76	0730		5.41	730	6839	86	449	2125	23291	25941	4786	38306	123	52	-9.6
		04/22/76	1130		5.57												
		04/22/76	1530		5.44	678	11359	91	81	4184	27958	32973	6115	50436	98	53	11.0
		04/22/76	1930		5.29												
		04/22/76	2330		5.03	835	8824	94	151	7237	22140	30624	5391	45662	114	51	-6.0
		04/23/76	0330		5.37												
		04/23/76	0730		5.29	644	7519	71	83	2759	25436	28747	4431	40943	110	52	-10.3
		04/23/76	1130		5.23												
		04/23/76	1530		5.33	687	6349	68	79	2985	21397	24979	4254	37519	113	50	-14.0
		04/23/76	1930		5.25												
		04/23/76	2330		5.03	775	6159	102	85	3731	17078	21555	5318	33248	107	50	-9.5
		04/24/76	0330		4.94												
		04/24/76	0730	TS	5.10	718	6299	84	95	3121	22634	26379	5495	38446	124	50	-25.7
		04/24/76	1130		4.91												
		04/24/76	1530		5.35	740	6859	78	90	4568	18420	23902	5672	36427	102	50	-8.4
		04/24/76	1930		5.07												
		04/24/76	2330		5.38	772	8539	82	86	5518	19244	25866	5405	39647	96	50	7.5
		04/25/76	0330		5.20												
		04/25/76	0730		5.31	752	7459	77	102	1945	20838	23172	4563	36136	109	50	5.3
		04/25/76	1130		5.36											50	
		04/25/76	1530		5.25	679	6079	73	83	2103	18276	20800	4786	32079	101	50	-5.3
		04/25/76	1930		5.17											50	

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
583-25	2816	04/25/76	2330	TS	5.25	667	6279	80	80	3143	22902	26674	4254	37405	117	50	-21.6
		04/26/76	0730		5.34	686	6539	59	104	2329	18112	20907	4343	32172	96	50	3.4
		04/26/76	1130		5.20												
		04/26/76	1630		5.28	647	6999	56	97	3392	20047	24117	3900	35148	95	50	0.2
		04/26/76	1930		5.27												
		04/26/76	2330		5.29	760	7459	90	213	2849	20075	23494	3900	35746	107	51	9.3
		04/27/76	0730	TS	5.41	652	6139	63	197	1243	16828	18320	3013	28155	90	50	14.6
		04/27/76	0900														
		04/27/76	1130		5.35												
		04/27/76	1530		5.41	775	5939	88	134	2035	17153	19595	2481	28605	110	50	10.6
		04/27/76	2330		5.45	762	5239	56	106	2397	18368	21244	2659	29587	124	50	-9.1
		04/28/76	0330		5.25												
		04/28/76	0730		5.41	790	5719	58	108	1243	17987	19479	2836	23741	113	50	5.8
		04/28/76	1030		5.86												
		04/28/76	1530		5.70	794	7019	61	112	1130	21584	22940	2481	33181	123	50	12.0
		04/28/76	2330		5.39	766	5559	76	110	1515	14202	16020	4254	26482	97	51	9.6
		04/29/76	0730		5.20	867	7079	81	106	3166	17217	21016	4363	33479	110	51	3.6
		04/29/76	1530		5.29	735	6599	76	104	2261	18379	21092	4609	32813	110	50	3.2
		04/29/76	2330		5.41	932	5974	152	87	1040	19301	20549	3369	30754	129	52	3.5
		04/30/76	0730		5.33	753	5759	55	84	2442	17444	20374	3545	30097	113	50	-1.5
		04/30/76	1530		5.50	784	6099	94	110	1492	18234	20024	2559	29472	115	51	10.2
		04/30/76	2330		5.43	1132	6339	53	88	2374	20525	23374	2481	32972	175	52	4.5
		05/01/76	0730		4.98	704	6439	53	90	4151	17003	21984	2304	30744	95	51	8.2
	2821	04/22/76	0730		5.41	730	6839	86	449	2125	23290	25840	4786	38305	123	52	-9.6
		04/23/76	0730														
		04/24/76	0730														
		04/25/76	0730														
		04/27/76	0730														
		04/28/76	0730														
		04/30/76	1530														
584-2A	2816	05/04/76	0730	TS	5.14	647	10099	63	64	5970	23714	30878	3013	43590	97	50	16.1
		05/04/76	1530		5.17	700	11759	91	106	5156	34517	40704	3190	55519	113	51	7.1
		05/04/76	2330		5.31	666	10679	66	124	3619	30919	35261	3013	49025	109	52	10.6
		05/05/76	0730		5.75	202	8339	68	104	8051	22445	32106	2659	41868	30	50	-5.9
		05/05/76	1530		5.86	175	11679	72	104	11760	25504	39616	6027	55321	23	50	-2.0
		05/05/76	2330		5.75	279	9999	85	68	701	30612	31453	5318	47962	48	52	4.4
		05/06/76	0730		5.82	238	9059	90	100	5247	20259	26555	5495	40458	30	50	7.7
		05/07/76	0730		5.71	250	10679	79	103	6694	25237	33270	4431	47473	35	50	6.5
		05/07/76	1530		5.98	732	5799	71	85	859	19082	20113	5318	31944	115	52	-9.6
		05/07/76	2330		5.66	203	9819	69	62	9499	25170	36569	4451	49293	30	51	-7.8
		05/08/76	0730		5.49	181	9479	63	82	12891	19946	35415	4254	46606	22	50	-8.0
		05/08/76	1530		5.70	142	8399	59	70	12891	12692	28161	3768	37621	13	52	3.0
		05/08/76	2330		5.36	204	13133	63	66	20907	19458	44546	5672	59368	20	50	1.0
		05/09/76	0730	TS	5.16	253	13918	66	70	23973	29460	58228	5140	72780	34	50	-17.6
		05/09/76	1530		5.43	333	11339	69	73	452	35380	35922	5672	53518	59	50	4.3

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
584-2A	2816	05/09/76	2330		5.36	352	9799	65	70	6332	21895	29493	5495	44808	45	50	7.2
		05/10/76	0730		5.37	329	9739	58	95	8368	23337	33379	5140	47066	45		-2.1
		05/10/76	1300														
		05/10/76	1530		5.48	270	10099	72	82	6332	30021	37619	4963	51839	45		-8.7
		05/11/76	0730		5.32	313	13978	96	78	12665	35095	50293	4963	67078	49		-2.0
		05/11/76	1530	TS	5.41	343	11199	73	97	9820	22578	33162	4254	47354	42		14.1
		05/11/76	2330		5.37	337	11559	71	83	7237	31149	39833	4786	55222	53		0.9
		05/12/76	0730		5.16	337	12278	101	86	7282	32619	41357	4431	57134	53	51	4.5
		05/12/76	0945														
		05/12/76	1530	MG	5.41	335	8419	96	93	4975	26974	32944	3900	44792	57	52	-11.2
		05/12/76	2330	TS	5.37	304	11539	103	105	10403	32920	45404	5395	60859	60	50	-13.2
		05/13/76	0730		5.35	493	11359	107	90	5880	32342	39398	6391	56652	81	50	-3.5
		05/13/76	1300														
		05/13/76	1530		5.25	630	11719	93	97	4071	36322	41207	7090	60022	112	52	-5.6
		05/13/76	2330	MG	5.19	675	16798	110	84	5426	39696	46207	8154	70943	105	50	16.2
		05/14/76	0730		5.28	619	12623	76	81	7689	36809	46036	8154	66050	106	51	-10.6
	2818	05/07/76	2330		6.54												
585-2A	2816	05/14/76	1530		5.21	672	13373	86	95	2714	35378	38635	6913	59231	108	52	12.3
		05/14/76	2330		5.25	687	10259	88	98	5428	29909	36423	5140	51609	111	50	-2.1
		05/15/76	0730		5.44	435	8759	86	51	2623	27107	30255	3545	42606	72	51	2.7
		05/15/76	1530		5.36	487	9859	52	61	4824	27077	32866	3545	45905	75	53	6.5
		05/15/76	2330	MG	5.62	655	11919	91	99	2714	29317	32574	4609	49404	95	50	20.7
		05/16/76	0730		5.37	675	9739	49	71	3618	30266	34608	4254	48572	114	51	-0.2
		05/16/76	1530		5.54	568	10679	53	65	3675	29873	34283	3545	48558	136	53	11.1
		05/16/76	2330		5.43	657	10099	50	60	4523	31430	36858	3900	50749	117	50	-1.0
		05/17/76	0730		5.41	639	9159	91	101	1990	32003	34391	3363	47351	118	51	-2.4
		05/17/76	1530		5.54	567	12338	47	61	4704	35451	41096	3190	56357	94	52	9.7
		05/17/76	2330		5.44	560	11359	37	63	5428	35709	42223	3190	56446	117	50	0.2
		05/18/76	0730		5.28	651	8599	52	57	2714	31317	34574	3545	46575	122	52	-10.2
		05/18/76	1530		5.33	658	9939	47	64	5247	27898	34194	4254	48167	102	50	3.2
		05/18/76	2330		5.26	742	10959	47	67	4885	31624	37486	4736	53110	121	51	2.9
		05/19/76	0730		5.28	693	12019	28	54	4523	37961	43389	4431	59659	124	50	-0.3
		05/19/76	1530	TS	5.20	772	10959	61	72	7237	36934	45618	5140	61175	143	50	-15.9
		05/19/76	2330		5.35	752	11999	65	76	3663	32770	37166	5672	54937	120	51	9.3
		05/20/76	0730		5.29	655	9919	52	60	3392	28604	32674	3545	46227	104	50	8.5
	2818	05/14/76	2330		6.29												
		05/17/76	2330		6.44												
586-2A	2816	05/20/76	1600		5.24	696	10419	46	52	6785	22857	30999	3013	43868	88	50	18.4
		05/20/76	2330		5.33	406	10559	60	87	2442	32856	35786	4077	50487	71	51	3.8
		05/21/76	0730		5.40	540	8479	44	52	2714	28038	31295	3013	42680	94	50	-1.2
		05/21/76	1530		5.54	356	9359	46	55	2442	29107	32037	3545	44910	60	50	3.1
		05/21/76	2330		5.50	462	8679	48	54	3528	24013	28247	3900	40684	79	51	5.7
		05/22/76	0730		5.16	483	8199	50	57	4432	22476	27794	3900	39597	71	50	1.9
		05/22/76	1530		5.41	222	11439	52	60	18545	22071	44325	4431	56820	26	50	-9.6
		05/22/76	2330		5.50	370	9679	42	81	5608	25445	32175	4963	46168	55	51	1.1

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
586-2A	2816	05/23/76	0730		5.24	360	9779	45	30	4071	24289	29174	4963	43537	51	50	9.4
		05/23/76	1530		5.25	270	11559	41	61	14474	26276	43445	4077	56778	37	50	-3.7
		05/23/76	2330		5.25	596	10399	43	85	16284	12212	31753	4609	44228	43	51	11.0
		05/24/76	0730		5.24	798	9579	68	43	4071	28539	33524	6027	49225	129	50	-4.3
		05/24/76	1600		5.37	688	10119	75	79	4975	28500	34470	5140	49576	108	50	1.1
		05/24/76	2330		5.35	714	11639	81	81	6332	36153	43751	5495	60495	126	51	-6.7
		05/25/76	0445	TS	5.16	641	11199	62	70	9046	26272	31127	4609	45809	70	50	18.8
	2818	05/21/76	2330		6.33												
		05/24/76	2330		6.45												
587-2A	2816	05/31/76	1530		5.45	660	9979	38	83	3392	27044	31114	3190	44386	100	51	14.0
		05/31/76	2330		5.62	219	9619	43	25	11534	23183	37024	1240	45662	30	50	-0.1
		06/01/76	0730	CL	5.94	123	7459	44	30	12665	18806	34004	354	39481	17	50	-15.3
		06/01/76	1530		5.56	541	8799	40	99	2804	29341	32726	1950	43574	95	50	2.5
		06/01/76	2330		5.67	234	10579	38	103	2623	39437	41585	1772	53786	47	50	-3.3
		06/02/76	0730		5.90	256	9459	39	101	6100	26633	33953	1772	44360	40	50	4.8
		06/02/76	0800														
		06/02/76	1530	MG	5.64	262	11619	41	102	6785	29536	37678	1772	50117	40	51	14.3
		06/02/76	2330		5.45	247	10759	42	97	6332	29250	36848	1950	48677	39	50	8.8
		06/03/76	0730		5.54	544	10739	43	100	4975	33388	39356	1950	51739	95	50	4.4
		06/03/76	1530		5.31	640	10779	49	87	3483	34155	38335	1950	51143	113	50	7.6
		06/03/76	2300		5.45	691	10699	37	45	4523	35031	40459	2127	53153	125	51	1.6
		06/05/76	1530	MG	5.41	641	6839	33	61	3935	26362	31084	1418	39299	120	50	-15.0
		06/05/76	2330		5.41	572	11559	35	50	6332	33604	41202	1950	54102	96	51	7.1
		06/06/76	0730		5.16	820	11639	40	53	8594	36836	47149	1772	59954	145	50	-1.3
		06/06/76	1530		5.59	706	9299	41	58	4071	35468	40353	1772	51915	140	50	-10.8
		06/06/76	2330		5.25	708	10939	42	60	7463	29598	38654	1772	50582	110	50	8.1
		06/07/76	0730	TS	5.02	824	10959	47	64	13117	33485	49225	1950	60446	141	50	-14.1
		06/07/76	1530		5.32	804	8739	71	57	4523	31490	36919	1418	47102	149	50	-5.9
		06/07/76	2330		5.49	664	9859	39	58	4749	31112	35911	1643	48324	114	50	3.4
		06/08/76	0730		5.35	748	10239	45	87	4824	34138	39927	1772	51853	135	51	0.3
		06/08/76	1530		5.29	798	8719	43	60	6106	30440	37767	1418	47584	144	50	-8.6
		06/08/76	2330		5.32	716	9879	41	62	5580	31348	38404	2127	50053	123	50	-3.5
		06/09/76	0730		5.12	778	9999	40	63	3499	31822	43221	2127	54328	135	50	-11.0
		06/09/76	1530		5.31	666	8619	61	61	4523	27352	32780	1772	43054	111	50	1.9
		06/09/76	2330		5.27	744	9619	56	65	6332	31442	39040	1950	50208	130	50	-4.2
		06/10/76	0730		4.98	853	10199	47	70	7915	31598	41036	1950	52637	145	51	-2.8
		06/10/76	1530		5.27	697	8379	51	64	3844	31561	36174	2127	46723	133	50	-11.7
		06/10/76	2330		5.56	782	11719	39	64	4975	37207	43177	2570	57356	141	50	3.5
		06/11/76	0730		5.12	900	9239	50	69	10516	27522	40141	3013	51309	144	51	-13.8
		06/11/76	1530		5.12	693	9959	49	71	7689	27149	36376	2836	48446	105	54	2.4
		06/11/76	2330		5.15	700	9499	51	69	7915	29012	38510	1879	48125	116	50	-4.2
		06/12/76	0730		5.11	772	10159	50	97	7237	28431	37115	2304	49050	120	51	4.7
		06/12/76	1530		5.20	688	9339	41	54	5428	25914	33320	2127	44491	108	52	6.4
		06/12/76	2330		5.54	749	8739	39	56	2714	30458	33715	2215	44969	135	50	-0.7
		06/13/76	0730		5.52	714	8359	42	97	4297	31536	36692	2938	47093	136	51	-12.9

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
587-2A	2816	06/13/76	1530		5.27	752	10959	43	55	4297	31431	36587	2393	49930	122	53	12.0
		06/13/76	2330		5.21	732	10659	42	61	6332	31998	39596	2304	52128	123	50	3.0
		06/14/76	0530		5.14	746	8279	45	53	7011	24179	32592	1595	41908	115	50	-0.3
	2818	05/31/76	2330		7.19												
		06/07/76	2330		7.10												
		06/11/76	2330		6.35												
	2821	06/07/76	1530														
		06/11/76	1530														
588-2A	2816	06/16/76	0730		5.58	726	11399	57	53	2849	33446	36865	4077	52607	121	50	9.7
		06/17/76	1530		5.15	772	10679	68	47	4636	28185	33748	4963	49350	116	54	8.5
		06/17/76	2330	TS	5.45	758	10899	50	39	1413	29633	31329	5584	48376	117	50	13.6
		06/18/76	0730		5.43	624	11019	91	55	1809	32489	34663	4786	50873	104	50	9.3
		06/18/76	1530		5.25	726	11219	88	57	4749	29885	35584	5229	52023	122	50	8.2
		06/18/76	2330		5.12	808	10719	68	76	5429	26604	33118	6293	49956	115	50	6.5
		06/19/76	0730		5.43	710	10139	47	65	1809	29757	31928	5140	47671	115	50	7.3
		06/19/76	1530		5.78	806	11619	109	64	904	31095	32180	7002	51599	125	50	13.5
		06/19/76	2330		5.17	916	11119	49	87	4862	27283	33117	7830	52116	130	52	5.7
		06/20/76	0730	TS	5.10	802	10499	135	65	6106	33110	40437	7339	58056	139	52	-15.1
				TS	5.10	802	10499	135	65	6106	33110	40437	7339	58056	139	52	-15.1
		06/20/76	1530		5.52	748	12618	128	57	2261	34993	37706	8597	59402	122	50	5.1
		06/20/76	2330		5.57	844	13658	138	75	2487	43485	46463	9484	70171	159	52	-5.2
	2821	06/18/76	0730														
		06/18/76	0730														
589-2A	2816	06/21/76	1530		5.48	764	13358	129	78	226	37372	37643	8775	60702	128	50	9.9
		06/21/76	2330		5.56	700	10399	115	64	1583	32373	34273	8331	53565	120	52	-5.7
		06/22/76	0730		5.45	728	11879	119	64	2714	29755	33012	9661	54920	107	54	5.9
		06/23/76	1530		5.48	704	11259	112	130	3392	32522	35592	9395	57514	116	50	-5.9
		06/23/76	2330		5.40	644	11119	80	59	3731	31128	35605	6391	53141	103	50	3.2
		06/24/76	0730		5.31	683	9839	79	68	2261	30614	33327	6204	49747	116	53	-2.4
		06/24/76	1530	MG	5.52	628	12159	81	72	3844	27452	32065	4786	43022	85		22.6
		06/24/76	2330		5.70	648	8739	56	74	1583	28273	30173	4077	43450	111	50	1.6
		06/25/76	2330		5.48	590	10479	50	70	4749	36354	42053	3013	55305	112	50	-7.3
		06/26/76	0730		5.27	672	11859	45	76	5179	35419	41633	2936	56085	116	56	6.5
		06/26/76	1530		5.35	710	9579	44	85	3619	35398	39740	2491	51915	138	50	-8.3
		06/26/76	2330		5.25	654	9719	45	86	4342	30605	35815	2127	47578	112	50	3.7
		06/27/76	0730		5.33	678	11039	42	91	4161	37482	42475	2215	55708	127	54	-0.1
		06/27/76	1530		5.31	644	10359	44	87	5247	28798	35094	1772	46951	101	51	12.1
		06/27/76	2330		5.35	680	9419	48	107	3799	36968	41527	1418	52439	138	53	-11.2
		06/28/76	0730		5.32	636	11079	50	112	4464	32911	38268	1418	50670	107	56	11.8
		06/28/76	1530	MG	5.39	640	8559	45	90	4859	34646	40477	1418	50257	131	53	-19.2
		06/28/76	2330		5.50	584	10179	40	90	3614	35154	39491	1418	51079	109	50	1.0
		06/29/76	0730		5.52	644	11439	43	86	6093	35090	42399	1329	54714	112	50	5.3
		06/29/76	1530		5.44	749	9199	45	84	3160	36889	41687	1240	51370	153	52	-10.5
		06/29/76	2330		5.73	641	9739	41	51	3424	31321	35430	1152	46407	112	54	8.0
		06/30/76	0730		5.41	612	10509	42	92	4772	33031	38757	1329	50577	106	50	7.7

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
589-2A	2816	06/30/76	1530		5.35	874	9679	45	87	4523	30843	36271	1963	47714	148	52	8.9
		06/30/76	2330		5.40	641	9919	44	88	3663	29036	33432	2127	45518	104	55	11.3
		07/01/76	0500		5.43	688	11119	46	94	3844	32562	37175	4254	52607	114	50	6.2
	2821	06/29/76	1530														
601-2A	2816	07/02/76	0730		7.23	331	1079	37	97	316	3506	3865	709	6075	42	50	7.8
		07/02/76	1530		7.35	494	1011	35	95	189	4270	4497	386	6988	73	50	-6.1
		07/04/76	0730		6.04	622	1489	48	53	90	5038	5146	1063	8493	80	50	12.7
		07/06/76	1530		6.85	171	2269	22	35	723	8403	9271	886	12509	23	50	-10.6
		07/06/76	2330		7.71	139	2764	23	36	723	7008	7876	1240	11933	17	50	15.8
		07/07/76	0730		7.46	628	2319	23	34	316	8136	8515	1152	12698	90	51	6.7
		07/07/76	1530	TS	7.49	236	2284	20	34	407	9709	10127	1053	13753	42	50	-20.3
		07/07/76	2330		6.66	307	2604	20	35	407	8491	8979	1240	13124	44	50	4.1
		07/08/76	0730		6.77	249	3049	21	33	565	9414	10092	1240	14568	35	52	7.5
		07/08/76	1530	MG	7.36	94	2509	15	29	1167	8892	10292	1276	13982	15	50	-17.8
		07/08/76	2330		7.22	130	3489	21	35	1040	9202	10450	1595	15512	17	50	11.1
		07/09/76	0730		7.07	698	2544	15	15	497	8697	9253	2570	15026	97	52	-6.7
		07/09/76	1530		7.20	179	3079	22	42	678	8079	8593	1418	13497	22	55	14.8
		07/09/76	2330		7.57	398	2679	22	43	316	8778	9157	1584	13920	57	50	1.7
		07/10/76	0730		7.07	637	2699	18	14	407	9499	9987	1595	14969	94	52	0.8
		07/10/76	1530		7.33	247	2979	20	39	579	8261	8956	1772	13997	32	54	8.8
		07/10/76	2330		6.79	453	2969	22	39	361	9102	9535	1684	14630	62	50	8.5
		07/11/76	0730		7.08	632	2599	25	37	361	8355	8788	2038	14147	84	51	5.9
		07/11/76	1530		7.41	593	3054	23	36	271	9515	9840	1772	15254	81	53	9.9
		07/11/76	2330		7.04	538	2669	20	41	271	9074	9399	1772	14585	78	50	1.1
		07/12/76	0530		6.81	552	2769	28	48	226	8560	8831	2304	14487	74	54	3.5
	2821	07/02/76	1530														
		07/06/76	1530														
		07/07/76	1530														
		07/08/76	1530														
		07/09/76	1530														
		07/10/76	1530														
		07/11/76	1530														
602-2A	2816	07/12/76	2330		6.58	293	2994	22	42	746	7454	8349	2570	14121	35	50	6.3
		07/13/76	0730		7.28	275	2684	19	39	171	9246	9451	2491	14915	42	50	-12.9
		07/13/76	1530		6.83	208	2529	21	40	180	6637	6853	2481	12096	25	54	3.5
		07/13/76	2330		7.39	331	3339	23	40	814	8337	9314	2481	15365	39	52	10.0
		07/14/76	0730		6.75	579	2704	21	34	180	8803	9019	2659	14979	80	50	-3.8
		07/14/76	1330														
		07/14/76	1530		7.03	352	3019	22	33	384	7570	8031	2570	13950	41	54	10.5
		07/14/76	2330		6.79	445	2689	22	38	294	7321	7674	2393	13202	54	52	7.4
		07/15/76	0730		7.19	383	2724	41	36	226	7235	7596	2659	13304	46	50	6.0
		07/15/76	0800														
		07/15/76	1530		6.70	538	3144	36	64	316	8157	8536	2659	14914	64	53	12.5
		07/15/76	2330		7.20	788	3159	35	67	271	8495	8820	2747	15562	93	52	13.7
		07/16/76	0730		6.94	406	2769	30	56	248	7136	7454	2836	13481	48	50	6.4

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULPATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
602-2A	2816	07/16/76	1530		7.00	262	3209	27	54	407	7250	7739	3102	14311	29	50	11.1
		07/16/76	2330		6.70	220	2849	19	24	497	6549	7145	2836	12994	24	52	7.3
		07/17/76	0730		6.74	165	2804	19	25	610	6350	7582	2334	12777	19	50	7.3
		07/17/76	1530		6.60	140	2759	20	25	814	7792	8759	2605	14145	19	50	-8.6
		07/17/76	2330		7.00	184	3014	19	25	746	7346	8241	2304	13638	22	50	8.5
		07/18/76	0730		6.98	406	2889	29	65	325	9272	9662	2394	15290	58	50	-2.0
	2821	07/13/76	1530														
		07/14/76	1530														
		07/15/76	1530														
		07/16/76	1530														
		07/17/76	1530														
603-2A	2816	07/20/76	0730		6.99	696	3084	38	65	203	7933	8177	2836	14855	80	54	14.2
		07/20/76	1530		7.02	732	2919	41	66	316	7991	8370	3368	15433	87	50	3.3
		07/20/76	2330		6.91	683	2534	37	58	334	8221	8682	3190	15107	92	50	-10.2
					6.91												
		07/21/76	0730		6.64	656	3034	33	55	284	8784	9125	2925	15771	84	53	4.5
		07/21/76	1530		6.78	672	3364	40	63	316	8886	9265	3368	16709	80	50	8.2
		07/21/76	2330		6.66	307	2889	26	65	429	7599	8114	2836	14151	38	51	2.7
		07/22/76	0730		6.94	512	3209	36	66	398	8501	8979	2836	15558	62	55	8.8
		07/22/76	1530		6.82	323	2979	37	64	497	7932	8528	2659	14491	40	50	4.5
					6.82												
					6.82												
		07/22/76	2330		6.82	337	3004	32	52	678	8175	8989	2659	14937	43	50	1.7
		07/23/76	0730		6.84	668	3214	38	65	339	9330	9737	2747	16401	86	53	6.9
		07/23/76	1530		6.70	742	3484	41	70	497	9226	9822	2925	16995	87	52	12.3
		07/23/76	2330		7.11	806	2769	37	52	226	8971	9242	2659	15520	103	50	1.3
		07/24/76	0730		6.91	641	3489	36	63	384	9318	9779	3013	16944	78	54	10.4
		07/24/76	1530		6.83	758	3109	32	67	497	8151	9747	3456	16070	98	52	5.8
		07/24/76	2330		7.66	640	2874	24	34	452	7742	8284	3545	15311	76	50	-0.8
		07/25/76	0730		7.07	663	3759	44	73	384	9213	9674	3279	17415	76	54	15.1
		07/25/76	1530		7.58	800	3519	47	71	271	8823	9148	3988	17519	91	50	9.1
		07/25/76	2330		7.15	840	3479	35	38	248	9279	9577	3368	17287	100	50	11.0
		07/26/76	0730		6.94	522	3659	40	62	384	10752	11213	3279	13701	71	53	1.4
		07/26/76	1530		6.73	463	3599	32	63	723	8445	9313	3190	16515	52	52	11.9
	2821	07/20/76	1530														
		07/21/76	1530														
		07/22/76	1530														
		07/23/76	1530														
		07/24/76	1530														
		07/25/76	1530														
		07/26/76	1530														
604-2A	2816	07/28/76	2330		6.91	664	3469	37	79	316	8452	8831	3102	16110	75	53	15.7
		07/29/76	0730		6.82	691	3389	34	66	294	9070	9423	3456	17000	84	50	7.2
		07/29/76	1530														
		07/29/76	2330		7.11	746	3044	41	69	271	7263	7588	3456	14890	80	54	12.3

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
604-2A	2816	07/30/76	0730		6.66	761	3504	43	72	226	9257	9528	3545	17408	91	50	9.6
		07/30/76	1500		7.06	766	2874	34	53	271	8329	8654	2836	15163	95	50	6.2
		07/30/76	2330		6.61	722	3059	42	71	284	8215	8556	3102	15495	86	54	8.8
		07/31/76	0730		6.82	709	3299	42	73	226	8526	8697	3279	16254	84	50	10.6
		07/31/76	1530		7.02	686	3204	51	86	180	8520	8736	3130	15757	84	50	7.0
		07/31/76	2330		6.92	754	3054	46	82	248	7658	8156	3102	15144	86	54	12.2
		08/01/76	0730		6.95	749	2919	49	76	271	9308	9633	3279	15651	92	50	3.7
		08/01/76	1530		6.75	697	2959	51	70	248	7352	7650	2925	14302	77	51	14.3
		08/01/76	2330		6.89	728	2929	47	66	294	7635	7958	3013	14712	84	53	10.6
		08/02/76	0730		6.94	740	3174	49	72	452	7902	8444	3190	15579	83	53	12.0
		08/02/76	1530		6.99	624	2914	42	83	244	8139	8432	3013	15059	77	50	5.2
		08/02/76	2330	MG	6.91	736	3334	43	79	248	8682	8980	2925	16047	86	50	14.4
		08/03/76	0730		6.94	739	3039	45	69	294	8985	9338	3013	16183	95	51	3.8
		08/03/76	1530		7.02	850	2969	34	67	316	8390	8769	2304	14950	103	50	14.5
		08/03/76	2330		6.71	682	3084	49	100	316	8939	9316	2925	16094	87	50	5.4
		08/04/76	0530	MG	6.66	700	3599	36	82	180	9436	9654	3013	17048	84	51	14.6
	2821	07/29/76	1537														
		07/30/76	1530														
		08/02/76	1530														
		08/03/76	1530														
605-2A	2816	08/06/76	0330		6.95	592	2429	36	79	135	7682	7844	2747	13700	79	50	-3.4
		08/06/76	0730		6.89	432	3304	39	75	226	9362	9633	2836	16274	56	50	5.5
		08/06/76	1530		6.95	286	3294	29	67	488	8415	9001	2659	15239	35	52	9.0
		08/06/76	2330		6.79	352	3454	34	70	158	9279	9469	2921	16268	45	50	8.7
		08/07/76	0730		7.00	470	3094	29	82	248	8935	9233	2659	15517	61	52	5.0
		08/07/76	1530		6.89	347	2984	20	47	352	7356	7778	2570	13676	40	55	11.5
		08/07/76	2330		6.91	436	3169	30	69	452	7953	8495	2925	15074	51	55	9.2
		08/08/76	0730		7.08	463	3199	29	69	407	8639	9127	2747	15563	58	51	7.5
		08/08/76	1530		6.83	433	3104	30	71	370	7819	8263	2659	14486	51	54	11.8
		08/08/76	2330		6.85	408	3084	34	72	339	8227	8634	2747	14911	50	55	7.3
		08/09/76	0730		7.10	401	3259	34	87	361	8652	9085	3013	15847	49	52	7.1
		08/09/76	1530		6.87	366	3049	36	92	497	7878	8474	2659	14577	44	54	7.9
		08/09/76	2330		6.92	252	2829	35	99	316	8044	8423	2393	13967	33	55	2.6
		08/10/76	0730		7.08	271	3329	31	70	452	8513	9055	2481	15147	33	50	11.0
		08/10/76	1530		6.98	398	2934	28	70	393	8423	8895	2836	15082	52	54	-0.4
		08/10/76	2330	TS	6.94	350	3299	25	72	520	7407	8031	2836	14509	38	51	15.7
		08/11/76	0730		7.04	437	3004	29	70	407	8399	8887	3013	15355	55	50	0.7
		08/11/76	1530		6.94	293	3084	27	68	465	7621	8179	2393	13951	34	55	12.3
		08/11/76	2330		7.03	300	2829	35	81	610	7341	8073	2570	13766	36	52	4.3
		08/12/76	0730			297	3329	25	66	520	8241	8865	2836	15314	35	50	9.2
		08/12/76	1930		6.83	409	2579	23	62	180	7625	7641	2393	13271	54	54	1.7
		08/12/76	2330		6.94	333	2849	32	56	633	6828	7588	2570	13341	39	52	9.5
		08/13/76	0730		6.98	297	3159	23	58	678	7546	8360	2659	14330	24	50	6.7
	2821	08/06/76	1530														
		08/07/76	1530														

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
605-2A	2821	08/08/76	1530														
		08/09/76	1530														
		08/10/76	1530														
		08/11/76	1530														
606-2A	2816	08/13/76	1530	Y	7.75	636	3469	24	61	67	10125	10205	2659	17041	94	55	10.1
		08/13/76	2330		8.00	758	3109	26	67	339	9044	9451	2747	16090	96	53	7.5
		08/14/76	0730		7.83	695	3054	24	63	262	8825	9139	2431	15404	88	50	9.8
		08/14/76	1530		7.93	667	2809	27	67	226	8358	9229	2373	15147	91	55	2.9
		08/14/76	2330		7.94	675	2799	22	88	271	8911	9236	2127	14893	92	52	5.6
		08/15/76	0730		7.95	836	2944	19	66	226	9340	9611	2481	15912	112	50	5.7
		08/15/76	1530		7.95	659	2854	20	61	384	8291	8752	2304	14573	93	55	8.5
		08/15/76	2330		7.98	702	3274	20	64	207	9525	9769	2659	16047	94	50	4.1
		08/16/76	0730		7.89	794	2984	25	67	271	9062	9387	2481	15684	103	51	7.8
		08/16/76	1530		8.21	632	2789	29	69	45	8433	8487	2393	14390	83	55	7.5
		08/16/76	2330		7.91	628	2574	34	97	384	7928	8383	1961	13506	82	52	8.1
		08/17/76	0730		7.91	762	2644	22	61	180	9001	9217	2570	15240	107	52	-2.4
		08/17/76	1530		7.89	788	2519	23	60	361	7046	7479	2836	13633	92	54	5.4
		08/17/76	2330		8.03	697	2914	20	46	303	8865	9250	2659	15525	92	50	3.2
		08/18/76	0730		7.93	706	3159	22	49	407	8729	9217	2747	15819	87	52	9.4
		08/18/76	1345		7.93	752	3079	23	50	316	8850	9229	2747	15817	94	54	8.0
	2821	08/13/76	1530														
		08/14/76	1530														
		08/15/76	1530														
		08/16/76	1530														
		08/17/76	1530														
		08/18/76	1345														
607-2A	2816	08/19/76	1600		8.19	466	3629	19	48	723	9953	10821	2659	17497	60	54	7.3
		08/19/76	2330		8.16	114	4369	22	60	2059	10833	13303	3013	20469	14	50	1.5
		08/20/76	0730		8.06	226	4769	19	56	1718	13442	15504	2481	22711	32	52	3.2
		08/20/76	1530		7.67	150	5979	20	60	1718	15311	17373	2659	25897	20	52	13.0
		08/20/76	2330		7.83	143	5779	17	68	2008	14988	17398	2659	25668	20	50	9.9
		08/21/76	0730		7.98	213	5639	23	65	1199	14554	15992	2481	24173	28	54	15.6
		08/21/76	1530		7.87	75	5099	21	47	1062	14633	15907	2393	23330	11	55	6.3
		08/21/76	2330		8.20	321	5259	20	47	972	14386	15552	2707	23912	44	50	10.0
		08/22/76	0730		8.00	604	4619	21	63	497	16834	17430	2836	25474	100	54	-7.3
						646	4619	21	63	497	16934	17430	2836	25516	107		-6.8
		08/22/76	1530	CA	7.95	622	4859	23	74	701	15984	16925	2570	24833	96	54	2.5
				CA	7.95	295	5579	23	74	1085	15221	16523	2570	24847	41	54	12.6
		08/22/76	2330		7.95	678	4859	25	66	701	15984	16925	2659	24972	104	54	2.5
		08/23/76	0730		7.90	655	5149	24	67	655	15371	16157	2570	24491	94	54	10.9
		08/23/76	1530		7.94	760	4699	23	72	452	14739	15281	2570	23315	111	54	8.6
		08/23/76	2330		7.83	535	4439	16	46	393	13446	13918	2304	21179	76	50	9.9
		08/24/76	0730		7.91	607	4549	17	48	600	16094	16314	2659	24974	93	54	3.3

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SUL-FATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
607-2A	2816	08/24/76	1530		7.94	644	4259	18	50	542	13367	14017	2304	21184	93	51	7.2
		08/24/76	2330		7.95	530	5209	24	65	416	16343	16842	2393	24980	80	52	8.6
		08/25/76	0530		7.91	525	4659	22	68	542	17087	17737	2570	25573	104	54	-5.9
		08/30/76	1530		7.91	600	4889	30	64	624	15883	16632	2481	24571	92	50	4.3
		08/30/76	2330		8.04	696	5589	26	72	723	17594	18462	2925	27577	92	54	5.7
		08/31/76	0730		7.91	642	5129	26	68	452	15658	16200	2401	24376	94	51	11.4
					7.91	642	5129	26	68	452	15658	16200	2481	24456	94	51	10.9
		08/31/76	1530		8.07	425	4839	27	65	633	15189	15949	2659	23840	64	50	3.6
		08/31/76	2330		8.03	605	5069	25	64	407	17270	17753	2659	26099	97	54	1.2
		09/01/76	0730		7.89	658	4739	30	72	542	15507	16157	2570	24118	100	51	4.0
		09/01/76	1530		7.70	592	5059	26	67	588	16262	16966	2747	25341	99	53	4.0
		09/01/76	2330		7.90	624	4359	24	61	271	14872	15197	2304	22515	97	54	2.8
		09/02/76	0730		7.87	603	4539	27	76	452	14399	14941	2304	22406	90	54	7.6
		09/02/76	1530		7.86	380	3909	12	45	624	13786	14535	2491	21137	62	50	-11.6
					7.86	380	4650	12	45	624	13786	14535	2491	21978	54	50	7.6
	2821	08/19/76	1600														
		08/20/76	1530														
		08/21/76	1530														
		08/22/76	1530														
		08/23/76	1530														
		08/2[illegible]/76	1530														
		08/30/76	1530														
	2825	08/31/76	1530		5.06	1034	5179	23	63	2723	17543	20811	2481	29046	160	50	-4.8
		09/01/76	1530		5.24	850	5009	26	68	2714	16379	19636	2659	27705	129	53	-5.8
		09/02/76	1530		5.16	896	4509	22	65	2668	15026	18228	2881	26067	127	50	0.4
608-2A	2816	09/03/76	1530		8.20	629	5219	23	66	361	15681	16114	2570	24548	91	53	12.0
		09/03/76	2330		7.91	580	4389	22	64	316	14668	15047	2481	22520	99	56	2.4
		09/04/76	0730		7.85	795	4959	24	60	361	14700	15133	2481	23381	111	54	14.5
		09/04/76	1530		8.08	258	4649	26	66	873	13451	14499	2304	21627	37	50	7.9
		09/04/76	2330		7.87	644	5179	25	65	452	15893	16435	2127	24385	95	55	12.8
		09/05/76	0730		7.96	738	4959	24	63	280	14050	14386	2481	22595	100	54	17.4
		09/05/76	1530		7.87	710	4659	25	68	814	15244	16221	1950	23470	107	54	6.8
		09/05/76	2330		7.91	586	4989	25	71	407	16438	16926	2215	24731	91	54	6.7
		09/06/76	0730		7.75	944	4769	23	75	452	14911	15453	2127	23301	135	54	13.7
		09/06/76	1530		7.31	561	4399	24	65	361	16044	16477	2038	23492	93	54	-2.0
		09/08/76	0730		8.04	80	4869	20	53	2284	10905	13646	2659	20870	9	50	11.0
	2825	09/03/76	1530		5.02	1094	5559	24	70	2329	21964	24759	2659	33699	194	55	-14.7
		09/04/76	1530		5.02	652	4049	27	71	3075	13368	17058	2833	24075	93	50	0.0
		09/05/76	1530			660	4699	23	66	2949	14275	17814	1961	24633	92	5	4.1
		09/06/76	1530		5.06	914	4739	24	63	1899	15142	[illegible]	1950	25331	123	55	0.2
608-2B	2816	09/07/76	0330		7.36	210	4499	22	61	859	12629	13660	1879	20159	29	55	11.9

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
608-2B	2815	09/07/76	0730	CL	7.91	125	4009	36	54	1130	10051	11407	1595	17000	15	50	15.7
		09/07/76	1130		7.91	406	4059	35	50	1280	10426	11962	1950	18206	30	50	14.8
		09/07/76	1530		8.02	78	4279	17	58	1696	11625	13660	1950	19703	11	55	5.2
		09/07/76	1830		7.34	70	4379	17	55	2467	10932	13316	1950	19890	9	54	5.2
		09/07/76	2330		7.99	77	5509	18	57	3769	11279	15732	2334	22977	8	51	14.9
		09/08/76	1530		9.03	101	4479	23	52	1447	11177	12913	2325	20824	13	54	6.5
		09/08/76	2330		7.96	110	5269	24	54	3000	12386	15966	2836	23673	13	54	6.5
		09/09/76	0730		7.95	74	5289	24	62	3009	12254	15864	2836	23547	9	50	7.1
		09/09/76	1600		7.94	83	4849	26	65	2216	12623	15282	3013	22875	11	54	0.7
		09/09/76	2330		7.91	249	5739	24	75	882	13840	14838	3368	23777	33	52	10.9
		09/10/76	0730		7.98	396	4939	41	72	384	12652	13113	4431	22915	51	50	7.4
		09/10/76	1530		7.87	143	4769	24	56	2945	9439	13020	3300	21315	15	54	5.2
		09/10/76	2330		8.00	56	5059	25	57	2894	12172	15445	3190	23463	8	54	1.5
		09/11/76	0730		8.06	71	5049	20	53	2994	11247	14940	3368	22802	8	50	4.1
		09/11/76	1530		7.98	5	4829	19	55	4297	10639	15794	3102	22945	1	54	-4.1
		09/11/76	2330		7.93	43	5899	18	71	6083	11354	18654	3102	26570	5	52	2.7
		09/12/76	0730		8.10	53	4909	29	71	4025	10138	14963	3013	22238	5	50	3.2
		09/12/76	1530		7.94	47	4559	29	66	4116	9681	14620	3545	22043	5	54	-6.7
		09/12/76	2330		7.93	91	4099	28	73	3460	11578	15730	3279	23498	10	54	-0.4
		09/13/76	0600		7.97	61	5580	29	84	3777	12543	17075	3550	25624	7		2.1
	2825	09/08/76	1530		5.57	260	4509	22	55	2962	12240	15794	3013	23061	35	56	-7.1
		09/09/76	1600		5.83	179	4869	24	61	2917	13852	17352	3013	24915	25	55	-8.3
		09/10/76	1530		5.48	353	4839	24	58	6468	8160	15922	4077	23979	31	55	-6.8
		09/11/76	1530		6.19	72	5129	22	69	5835	12101	19103	3190	25409	9	55	-13.9
		09/12/76	1530		6.11	55	4819	26	59	5782	11087	17545	3368	24796	7	55	-14.5
609-2A	2816	09/13/76	1530	MG	6.68	81	3520	25	69	2827	10268	13660	2929	20019	11		-14.7
		09/13/76	2330		6.96	68	4630	27	69	2623	11045	14193	3283	21745	8		-0.2
		09/14/76	0730		6.92	64	4440	18	75	2691	10524	13753	2840	20652	8		1.3
		09/14/76	1530	T		96	4260	19	75	2171	10948	13553	2663	20232	12	6	0.2
		09/14/76	2330		6.94	108	4330	15	62	1899	11325	13604	3373	21112	14		-4.0
		09/15/76	0730		6.99	255	3850	32	76	1040	10341	11589	3639	19233	33		-3.3
		09/15/76	1345		8.11	198	3960	32	76	971	10033	11198	3373	18663	25	53	3.6
		09/15/76	1600		6.91	208	3970	21	73	1062	11361	12635	3550	20245	27		-6.9
		09/15/76	2330		6.96	534	4090	33	66	565	11249	11927	4148	20615	73		0.5
		09/16/76	0730		7.00	493	3860	32	76	565	11796	12474	3550	20372	70		-4.2
		09/16/76	1530		6.92	433	3400	33	74	588	11076	11782	3373	18977	64		-11.7
		09/16/76	2330		6.93	465	3870	24	56	518	10423	11045	3550	18906	59		4.1
					6.93												
		09/17/76	0730		6.90	428	4339	26	60	692	10012	10842	3300	19457	49	50	11.0
		09/17/76	1530		7.15	432	3539	27	57	437	10780	11376	3545	18677	66	54	-6.8
		09/17/76	2330		7.01	375	3379	16	62	474	10412	10981	3368	18693	53	50	-9.2
		09/18/76	0730		6.87	312	3359	17	66	565	9157	9845	3102	16599	40	53	0.6
		09/18/76	1530		7.19	584	3229	16	67	407	9245	9733	3369	16916	75	52	-0.1
		09/18/76	2330		7.01	742	3429	34	62	384	8581	9342	3722	16954	84	50	9.0

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
609-2A	2816	09/19/76	0730		6.85	468	3289	33	65	420	8161	8665	3279	15715	54	53	8.1
		09/19/76	1530		6.91	313	2909	33	71	520	8191	8815	3190	15227	41	52	-5.9
		09/19/76	2330		6.91	293	3333	34	61	520	7500	8124	3013	14754	32	50	12.3
		09/20/76	0730		7.07	375	3359	30	66	452	9646	10188	3102	17533	50	54	-6.5
		09/20/76	1530		6.90	697	3099	34	64	361	9841	10274	3102	17198	36	54	-2.9
		09/20/76	2330		6.85	782	3049	26	65	294	8047	8400	3900	16183	91	50	2.8
		09/21/76	0730		6.86	601	3359	27	63	226	9231	9502	3456	16973	75	50	4.7
		09/21/76	1530		6.84	732	2909	28	75	294	7862	8215	3722	15522	88	52	-1.3
		09/21/76	2330		6.82	712	3399	28	77	248	9097	9395	4077	17635	86	52	2.4
		09/22/76	0730		6.94	455	3349	27	75	497	8670	9266	3368	16441	55	53	4.4
		09/22/76	1530		6.95	249	2969	24	77	610	7290	8022	3190	14409	29	54	1.3
		09/22/76	2330		7.04	459	2939	25	75	384	7325	7786	3279	14547	52	54	5.6
		09/23/76	0730		7.15	466	3259	24	74	316	8951	9330	4077	17167	59	52	-5.1
		09/23/76	1530		7.00	579	3689	28	74	497	8563	9159	4609	18039	64	52	4.4
		09/23/76	2330		7.20	214	3109	27	68	655	8158	8944	3634	15865	27	53	-7.2
		09/24/76	0500		7.20	254	3569	28	72	588	9547	10253	3722	17720	33	52	-4.6
	2825	09/13/76	1530			169	4369	23	64	4161	11356	16349	3013	23155	22		-14.8
		09/14/76	1530			305	4279	17	73	3960	11915	16667	2481	23350	41		-12.9
		09/15/76	1600			629	4079	23	77	2759	11544	14855	3900	23011	83		-13.3
		09/16/76	1530			828	4099	32	75	1945	11966	14300	3368	22313	110		-2.8
		09/17/76	1530		4.90	286	4099	26	62	2420	9347	12251	3456	19686	33	54	0.2
		09/18/76	1530		5.04	1116	3249	15	64	1990	9842	12230	3456	19732	141	52	-8.2
		09/19/76	1530		5.04	1072	3189	17	72	2555	8795	11861	3545	19245	126	52	-9.0
		09/20/76	1530		5.08	1212	3139	31	67	1945	9999	12333	3190	19583	157	54	-7.0
		09/21/76	1530		5.00	1196	2929	30	68	1809	8511	10682	3811	18354	141	52	-8.5
		09/22/76	1530		4.83	702	3349	27	75	2736	7677	10960	3368	17934	74	54	-3.0
		09/23/76	1530		4.83	1128	3579	25	77	2171	9793	12398	4975	21648	134	52	-11.8
610-2A	2816	09/24/76	1530		7.89	165	3189	29	71	655	7699	8485	3013	14821	19	50	4.4
		09/24/76	2330		7.94	193	3619	30	93	859	7913	8944	3279	15986	21	52	10.4
		09/25/76	0730		7.87	212	3489	27	68	769	9309	10231	3722	17535	27	54	-5.8
		09/25/76	1530		8.02	175	3069	30	70	610	7475	8207	3031	14460	21	50	3.0
		09/25/76	2330		7.99	187	2969	26	70	814	7602	8579	3279	14949	23	54	-5.7
		09/26/76	0730		7.87	129	3519	27	66	1176	8391	9802	3722	17530	15	54	-3.4
		09/26/76	1530		7.94	156	3469	27	74	746	8019	8914	3545	16036	18	50	3.6
		09/26/76	2330		7.97	181	3159	26	61	949	7290	8429	3545	15271	20	53	0.0
		09/27/76	0730		7.94	173	3219	25	74	723	7561	8429	2925	14700	20	54	6.7
		09/27/76	1530		7.89	215	2909	30	75	542	7771	8421	3190	14732	27	50	-4.7
		09/28/76	2330		7.73	107	3129	23	64	859	7141	8172	3013	14336	12	52	3.9
		09/29/76	0730		7.78	106	3349	23	71	972	7641	8807	3013	15175	12	53	5.4
		09/29/76	1530		8.00	138	3259	32	69	995	7848	9042	3190	15571	16	50	0.0
		09/29/76	2330		8.04	234	3419	33	71	633	8248	9008	3456	16094	27	54	3.8
		09/30/76	0730		8.02	182	3469	26	76	768	7958	8880	3190	15659	21	52	7.6
		09/30/76	1530		7.95	145	3259	26	80	1108	7292	8622	3279	15189	16	52	2.3
		09/30/76	2330		8.12	133	3689	26	72	1130	7717	9073	3102	15869	14	54	11.7
		10/01/76	0730		8.12	175	3629	26	84	882	8465	9523	3013	16274	20	52	8.8

LIQUID ANALYSES

RUN NO.	ANALY TICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SUL-FATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
610-2A	2816	10/01/76	1530		7.89	153	3469	31	72	904	8224	9309	3013	15966	18	54	5.9
		10/01/76	2330		7.98	181	3389	34	73	814	7989	8966	3102	15592	21	54	5.8
		10/02/76	0730		7.75	232	3549	31	80	555	8780	9566	2925	16252	28	52	8.2
		10/02/76	1530		8.04	262	2959	29	79	746	7556	8451	2659	14250	32	54	3.4
		10/02/76	2330		8.00	488	2869	27	73	407	7964	8472	3279	15127	61	54	-2.1
		10/03/76	0730		8.12	528	3359	30	83	542	8337	8987	3634	16513	61	54	5.4
		10/03/76	1530		7.98	824	3509	30	84	316	9273	9652	4254	18290	95	54	3.7
		10/03/76	2330		7.90	878	3329	9	74	316	8844	9223	4089	18069	103	54	-0.4
		10/04/76	0500		7.96	425	3439	31	74	384	9191	9652	3456	17000	53	54	2.9
		10/04/76	1530		8.03	724	3599	30	74	565	8898	9366	3811	17691	82	52	8.6
		10/04/76	2330		8.14	301	3309	32	73	429	8515	9030	3545	16204	37	54	0.9
		10/05/76	0730		8.04	297	3549	29	76	731	7901	8742	3545	16977	32	50	9.0
		10/05/76	1530		7.93	561	3569	27	78	361	8811	9244	4165	17512	66	54	3.1
		10/05/76	2330		7.94	948	3329	40	85	271	9446	9771	4254	19273	105	50	-1.0
		10/06/76	0730		7.35	532	3479	34	78	427	8709	9223	4077	17337	62	50	2.9
		10/06/76	1530		7.95	538	3149	32	65	316	9402	9781	4431	17953	72	52	-13.5
		10/06/76	2330		8.17	644	3929	35	77	384	9684	10145	4254	19807	75	53	7.7
		10/07/76	0730		7.34	814	4069	46	86	339	9095	9502	5052	19501	86	51	10.7
	2921	09/27/76	1530														
		09/29/76	1530														
	2825	09/24/76	1530		5.07	652	3339	30	72	2795	7482	10336	3190	17569	68	50	-1.7
		09/25/76	1530		5.22	540	3289	32	75	2261	8365	11073	3368	17430	63	50	-3.2
		09/26/76	2330		7.57	466	3359	29	76	2080	8316	10812	3358	17593	54	53	-5.7
		09/27/76	1530		5.06	628	3109	28	74	2533	8038	11078	3358	17778	73	50	-12.2
		09/29/76	1530		5.31	282	3299	26	68	2035	6815	9257	3545	16072	29	50	-1.5
		09/30/76	1530		5.21	376	3399	27	72	2349	7756	11175	3368	17847	41	52	-8.7
		10/01/76	1530		5.23	376	3269	29	71	2035	9183	11625	3013	17996	49	55	-11.8
		10/02/76	1530		5.25	560	3019	30	80	2264	7855	10596	2747	16575	66	54	-6.6
		10/03/76	1530		5.23	1082	3599	29	89	1311	10245	11818	4343	20698	134	54	-4.2
		10/04/76	1530		5.14	1050	3559	28	73	1651	9667	11668	3900	19949	125	52	-1.3
		10/05/76	1014			979	3569	28	75	1628	9500	11454	4254	19964	115	54	-5.4
		10/06/76	1530		5.11	926	3859	29	74	1809	10269	12440	4743	21309	111	52	-4.0
611-2A	2816	10/07/76	1530		7.87	1254	3669	46	85	271	9692	10017	5318	20535	138	52	6.9
		10/07/76	2330		8.02	255	4139	57	103	226	9907	10176	5211	13398	30	50	-0.1
		10/09/76	0730		7.83	786	4179	45	84	334	10092	10553	4786	20358	90	53	8.4
		10/08/76	1530		8.00	912	3879	46	86	294	10071	10424	5318	20606	108	54	0.5
		10/08/76	2330		7.87	946	4179	47	82	452	9796	10338	4875	20777	103	52	10.7
		10/09/76	0730		8.00	864	3719	38	55	217	9254	9514	5140	19287	98	52	2.6
		10/09/76	1530		8.00	858	3859	43	72	226	9166	9437	4963	19187	94	54	7.6
		10/09/76	2330		8.06	866	3639	53	86	113	9249	9385	5318	19324	100	50	0.5
		10/10/76	0730		8.08	904	4319	50	89	361	9617	10050	5495	20835	95	49	10.0
		10/10/76	1530		7.93	792	3519	54	80	226	9866	9137	5052	19569	91	54	0.2
		10/10/76	2330		8.11	772	4029	50	87	429	9823	10338	4609	19799	88	53	7.2
		10/11/76	0730		8.10	874	3979	52	74	339	10360	10767	5229	20907	104	54	0.9
		10/11/76	1530		7.78	914	3529	50	76	520	8127	8751	4963	18179	95	54	5.5

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
611-2A	2816	10/11/76	2330		7.86	1004	3333	68	109	294	8913	9266	6204	19925	117	50	-11.5
		10/12/76	0530		7.91	890	3939	65	103	158	8754	8944	5318	19227	92	52	10.1
	2825	10/07/76	1530		4.87	1384	3799	47	85	1470	9861	11625	5495	22141	135	53	-2.9
		10/08/76	1530		5.11	1068	4329	43	82	1334	10797	12398	5594	23237	123	54	-0.5
		10/09/76	1530		5.16	1156	3609	41	79	1945	9577	11711	5952	21259	131	56	-7.8
		10/10/76	1530		5.17	1048	3539	59	76	1967	9265	11625	5229	21183	120	55	-11.9
		10/11/76	1530		5.02	1122	3569	52	78	1424	9037	10746	5152	20374	124	56	-3.5
612-2A	2816	10/12/76	1530		7.90	896	3779	55	100	384	9448	9909	5584	20246	102	54	-0.9
		10/12/76	2330		8.04	842	3909	56	90	316	9723	10102	5310	20254	97	53	2.2
		10/13/76	0730		8.08	840	3419	53	93	226	9165	9437	4786	18543	100	54	-1.1
		10/13/76	1530		7.95	856	3989	50	90	452	9843	10385	5318	20598	98	54	2.4
		10/13/76	2330		7.95	872	3769	57	93	225	6964	7235	5672	17653	76	52	13.3
		10/14/76	0730		8.04	844	3999	59	97	90	9767	9875	6027	20453	95	52	0.2
		10/14/76	1530		7.95	826	3959	59	98	407	9749	10237	5672	20770	94	54	-0.3
		10/14/76	2330		7.91	760	3829	62	91	316	9550	9929	5495	20163	88	52	-1.0
		10/15/76	0730		7.67	912	3979	62	93	361	9124	9557	5850	20361	97	53	3.7
		10/15/76	1530		7.87	946	4479	59	92	407	9918	10406	5761	21662	100	53	9.9
		10/15/76	2330		7.93	970	4039	66	97	316	8850	9229	5672	20010	99	53	8.8
		10/16/76	0730		7.91	998	4139	63	104	248	9747	10045	5938	21237	109	52	4.3
		10/16/76	1530		8.15	636	4449	77	108	180	10913	11129	6027	22590	97	50	2.9
		10/16/76	2330		7.81	638	4099	60	89	271	9658	9983	5140	20165	93	50	8.0
		10/17/76	0730		8.04	842	4089	60	95	271	10442	10767	5406	21205	100	50	1.9
		10/17/76	1530		7.83	888	4629	68	92	542	10479	11129	5938	22636	97	53	7.3
		10/17/76	2330		8.10	880	4309	55	96	225	9551	9822	5495	20592	93	50	11.0
		10/18/76	0730		7.99	810	4149	60	97	203	10608	10852	5672	21599	97	52	0.2
	2825	10/12/76	1530		5.24	1152	3879	59	97	2012	9919	12333	5672	22790	131	56	-9.2
		10/13/76	1530		5.00	1102	4119	56	95	2080	10141	12637	6204	23797	123	56	-9.9
		10/14/76	1530		4.94	1166	4009	63	94	1309	10742	12313	5672	23555	139	55	-9.1
		10/15/76	1530		4.83	1150	4709	64	94	2171	10160	12765	6027	24395	118	53	3.1
		10/16/76	1530		4.65	1054	4419	73	110	1999	10213	12492	6027	23795	114	50	-1.9
		10/17/76	1530		4.58	1124	4699	71	55	2736	10203	13486	5850	24655	117	53	-1.1
613-2A	2816	10/18/76	1930		6.95	528	3779	40	96	226	9892	10163	4963	19624	77	50	-1.5
		10/18/76	2330		6.95	796	3959	34	85	361	9515	10048	5318	20398	91	51	2.2
		10/19/76	0730		6.67	766	4019	36	84	226	10668	10939	5572	21473	94	54	-4.0
		10/19/76	1530		6.79	936	4539	44	96	361	10037	10470	6204	22187	96	52	7.1
		10/19/76	2330		7.10	904	4339	43	105	243	9875	10173	5850	21364	97	52	7.3
		10/20/76	0730		6.74	433	4359	46	101	226	9665	9934	5850	21088	89	54	8.2
		10/20/76	1530		7.00	514	3459	57	89	316	9296	9675	4609	18779	108	50	2.0
		10/20/76	2330		6.74	930	4069	55	87	225	9286	9557	5229	19882	99	52	10.2
		10/21/76	0730		6.86	926	4319	59	91	316	9773	10152	6293	21477	83	54	3.1
	2825	10/18/76	1930		4.92	965	3739	41	54	2193	10119	12751	4992	22364	116	50	-11.6
		10/19/76	1530		4.65	1156	4599	45	102	2012	10307	12721	5672	23693	122	52	3.6
		10/20/76	1530		5.02	1024	3549	56	86	1221	9440	10905	4857	20233	120	50	-4.7
614-2A	2816	10/22/76	1530		8.37	107	2719	28	26	1557	8047	9675	2127	14411	15	52	-13.2

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
614-2A	2816	10/22/76	2330		8.56	641	3229	30	28	248	8643	8941	3634	16453	77	52	3.7
		10/23/76	0730		8.36	844	3409	33	30	316	8753	9132	4077	17462	97	54	6.1
					8.36											54	
		10/23/76	1530		8.16	760	3769	49	82	294	8961	9314	4796	18701	84	53	6.6
		10/23/76	2330		8.00	854	3639	35	31	271	8595	8920	4375	18300	92	52	6.1
		10/24/76	0730		7.98	892	3959	35	29	407	8708	9196	5229	19159	93	54	6.9
		10/24/76	1530		7.87	906	3469	48	84	316	8532	8911	4609	17964	100	52	5.8
		10/24/76	2330		8.02	889	3449	49	89	407	9090	9578	4796	18756	104	52	-0.6
		10/25/76	0930		8.12	812	3529	39	29	407	9791	10279	4875	19482	101	54	-5.5
		10/25/76	1530		8.43	926	3569	50	85	260	8933	9251	4520	18345	104	50	7.0
		10/25/76	2330		9.00	764	3799	46	82	361	8805	9238	4697	18556	83	52	8.5
		10/26/76	0730		7.83	758	3739	49	91	452	9631	10173	3545	18265	90	52	10.9
		10/26/76	1530		8.02	860	3490	48	90	326	9151	9542	4154	18119	101		5.6
					8.02	794	3135	48	90	326	9045	9436	4083	17521	100		-3.2
		10/26/76	2330		8.38	812	3640	52	76	320	8889	9273	4526	18315	91		6.8
		10/27/76	0730		8.08	730	3460	39	96	271	9118	9443	4439	18152	87		1.1
		10/27/76	1530		8.04	702	3120	18	73	360	8142	8574	3195	15610	82		8.7
		10/27/76	2330		8.05	542	3010	42	66	317	8937	9317	3954	16908	71		-10.2
		10/28/76	0730		7.87	652	3900	48	111	432	9165	9683	4349	18647	73	50	9.4
615-2A	2816	10/28/76	1530		6.93	600	3700	49	99	272	10289	10615	5058	20066	77	50	-7.3
		10/28/76	2330		7.02	708	4040	53	78	271	10400	10725	4438	19988	85	54	6.3
		10/29/76	0730		6.96	766	4029	48	97	113	11173	11309	4077	20303	98	50	6.4
		10/29/76	1530		6.86	762	3919	47	102	271	9996	10321	4165	19262	90	51	9.0
		10/29/76	2330		7.07	766	3149	72	77	180	9171	9387	4254	17669	97	54	-4.3
		10/30/76	0730		7.09	762	3629	61	84	226	9526	9797	3990	18288	92	51	7.4
		10/30/76	1530		7.11	800	3849	58	85	339	9490	9897	4609	19230	91	51	7.3
		10/30/76	2330		7.04	896	4109	58	85	271	9869	10194	5140	20428	100	54	7.8
		11/01/76	1530		7.10	966	3479	57	87	452	8017	8559	4431	17489	100	51	10.6
		11/01/76	2330		6.99	796	3529	52	84	407	9281	9769	4609	18758	94	52	0.3
		11/02/76	0730		7.04	768	3609	37	74	339	10201	10608	4431	19459	98	51	-2.1
		11/02/76	1530		7.00	822	3659	40	76	384	9287	9748	4786	19034	94	52	3.7
		11/02/76	2330		7.33	776	3949	45	69	497	9683	10279	4077	19096	83	52	10.4
		11/03/76	0730		7.50	784	3599	47	58	243	9577	9873	4786	19139	94	52	-0.9
	2825	10/28/76	1730		4.98	1080	3510	50	93	2353	8242	11066	5147	20475	112	50	-8.2
		10/28/76	2330		4.86	1164	3670	50	74	2081	11053	13550	4615	22707	150	54	-13.2
		10/29/76	0730		4.79	1148	4049	53	99	1831	11042	13239	4148	22370	139	50	0.7
		10/29/76	1530		4.96	1160	3679	60	79	1537	10389	12233	4254	21158	142	51	-2.6
		10/29/76	2330		4.98	1115	3129	70	75	2216	9022	11681	4254	19881	135	56	-14.1
		10/30/76	0730		4.94	1110	3649	65	87	1741	10101	12190	4165	20918	134	53	-2.9
		10/30/76	1530		4.95	1092	3979	63	89	1583	9844	11744	4609	21259	122	51	3.2
		10/30/76	2330		5.02	1144	3579	54	77	1221	10322	11787	5495	21892	142	48	-12.5
		11/01/76	1530		5.07	1430	3449	55	87	1357	8863	10491	4343	19584	154	51	5.2
		11/01/76	2330		5.04	1052	4059	57	88	1628	9642	11596	5052	21578	114	50	1.9
		11/02/76	0730		5.02	1025	3384	36	71	1583	9048	10948	4431	19578	119	51	-6.0
		11/02/76	1530		4.77	1195	3799	37	74	1176	10716	12127	4963	21960	146	53	-4.5

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
615-2A	2825	11/02/76	2330		5.00	1070	4039	44	80	2035	9940	12382	4254	21462	120	52	3.0
		11/03/76	0730		4.86	1075	3699	48	99	1176	10843	12254	4509	21549	137	52	-6.2
616-2A	2816	11/05/76	2330		8.04	2619	80	128	110	90	1909	2017	3251	8187	158	50	9.0
		11/06/76	0730		8.32	1700	196	22	71	339	1232	1639	2481	6041	90	53	-0.4
		11/06/76	1530		7.87	2940	128	24	71	180	580	796	4520	6443	50	50	10.0
					7.87											50	
		11/06/76	2330		8.10	2899	134	34	126	226	1374	1645	4077	8870	115	51	6.9
		11/07/76	0730		7.91	2889	242	34	106	90	1562	1670	3900	8823	123	52	14.0
		11/07/76	1530		8.02	2665	143	24	66	67	1449	1529	4077	8491	118	50	0.4
		11/07/76	2330		8.07	2815	155	34	131	45	1751	1805	3900	8831	142	50	6.6
		11/08/76	0730		8.00	2749	170	33	126	113	1244	1380	3811	8246	102	50	12.6
		11/08/76	1530		7.85	2714	178	37	121	226	1215	1486	3722	8213	99	50	12.2
		11/08/76	2330		8.02	2425	162	32	126	90	1187	1295	3811	7833	96	50	3.2
		11/09/76	0730		8.29	2425	158	32	119	180	1100	1316	3722	7776	87	51	6.6
		11/09/76	1530		7.79	2555	200	37	117	180	1610	1826	3722	8421	126	50	3.7
		11/09/76	2330		8.25	2759	195	37	119	45	2200	2254	4254	9608	171	52	-5.4
		11/10/76	0730		8.02	3162	253	39	116	135	1356	1518	5140	10208	109	51	3.8
		11/10/76	1530		7.95	3255	248	40	120	226	1440	1711	4609	9938	117	50	11.7
		11/10/76	2330		7.93	2585	254	41	116	135	1408	1570	4431	9070	109	52	1.2
		11/11/76	0730		5.74	3120	324	37	113	180	1683	1899	4697	10154	130	51	7.9
		11/11/76	1730		7.99	2564	261	36	122	90	1561	1669	4343	8377	119	50	-2.0
		11/11/76	2330		8.23	2549	278	39	116	113	2000	2136	4165	9262	148	52	-4.6
		11/12/76	0730		8.08	2579	300	39	121	113	1740	1876	4254	9146	129	52	-0.6
		11/12/76	1530		7.79	2614	313	41	117	90	1707	1815	4077	8959	127	50	5.1
		11/12/76	2330		7.98	2805	323	45	102	113	1552	1688	4254	9174	118	52	8.5
		11/13/76	0730		7.89	2630	342	47	101	67	1610	1690	4077	8874	118	50	8.4
	2825	11/05/76	2330		4.29	2975	91	128	109	361	3252	3685	3368	10284	259	50	-4.5
		11/06/76	0730		4.61	2632	205	25	71	1103	2070	3394	2659	8963	162	53	9.5
		11/06/76	1530		4.45	3115	135	25	72	1040	2277	3525	4431	11095	196	50	-17.0
		11/06/76	2330		4.31	3204	153	35	128	1221	1853	3318	4343	10937	153	53	-6.1
		11/07/76	0730		4.16	3245	161	33	109	927	2495	3607	4431	11401	202	52	-11.5
		11/07/76	1530		4.73	3489	164	26	68	1515	2004	3822	4165	11431	167	50	-3.5
		11/07/76	2330		4.60	2930	156	35	125	678	2223	3037	3793	9944	178	50	-3.9
		11/08/76	0730		4.41	3075	169	32	125	1062	1571	2845	3722	9776	128	50	5.4
		11/08/76	1530		4.33	3115	185	35	122	1311	1597	3270	3722	10187	139	50	1.3
		11/08/76	2330		4.39	2840	188	32	127	1402	1567	3249	4077	10233	126	52	-12.9
		11/09/76	0730		4.33	2775	213	33	121	1357	1663	3291	3811	9973	131	51	-9.6
		11/09/76	1530		4.37	2815	205	38	119	1176	2093	3504	3722	10168	163	48	-9.8
		11/09/76	2330		4.39	3049	212	37	121	723	1147	2015	4343	9632	94	52	5.6
		11/10/76	0730		4.50	3479	268	41	122	995	1906	3100	5229	12040	153	51	-5.7
		11/10/76	1530		4.33	3520	243	38	124	1311	2099	3672	4520	11655	169	48	-1.7
		11/10/76	2330		4.19	3944	259	44	119	1741	2090	4179	4077	11374	162	52	-13.4
		11/11/76	0730		4.20	3179	340	37	119	1713	2341	4403	4431	12165	176	51	-13.3
		11/11/76	1730		4.27	3959	275	38	120	1809	1877	4046	4254	11432	145	51	-13.5
		11/11/76	2330		4.61	3075	298	41	119	1130	1252	2608	4343	10258	99	52	3.3

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
616-2A	2825	11/12/76	0730		4.29	2995	308	40	120	1854	1506	3731	4431	11254	117	52	-12.8
		11/12/76	1530		4.32	3070	329	42	119	1718	2132	4194	4077	11487	161	51	-9.3
		11/12/76	2330		4.45	3334	329	51	112	1696	1968	4023	4431	11941	154	52	-5.1
		11/13/76	0730		4.12	3285	375	53	110	1560	2666	4538	4077	12126	198	50	-4.8
617-2A	2816	11/15/76	1930		8.06	2420	353	37	122	45	1326	1380	3722	8825	96	50	13.5
		11/15/76	2330		7.95	2650	375	39	125	0	1417	1417	4963	9569	104	51	-0.9
		11/16/76	0730		7.83	2010	557	39	124	180	827	1043	3900	7637	52	50	12.8
		11/16/76	1530		7.70	2430	429	41	126	226	1584	1955	3511	8647	109	50	9.6
		11/16/76	2330		8.08	2363	434	39	124	90	1613	1721	4431	9300	113	49	4.7
		11/17/76	0730		8.00	2579	463	41	120	180	1536	1752	3900	8819	107	50	14.7
		11/17/76	1530		8.07	2500	435	42	111	90	1747	1855	3651	8576	121	50	14.3
		11/17/76	2330		8.07	2520	443	45	107	158	1583	1773	4609	9465	110	51	0.0
		11/18/76	0730		7.91	3319	527	44	115	226	1569	1940	5052	10952	121	50	14.5
		11/18/76	1730		8.14	3400	526	44	107	203	1467	1711	5761	11509	108	51	9.0
		11/18/76	2330		8.00	3860	559	41	121	135	1486	1648	6115	12317	112	50	15.1
		11/19/76	0930		7.91	3189	538	41	125	180	1495	1711	5140	10708	107	50	13.3
		11/19/76	1530		8.08	3179	498	47	125	158	1623	1813	5140	10770	118	52	10.8
		11/19/76	2330		8.08	2859	592	48	122	90	1519	1627	4786	10516	103	50	14.1
		11/20/76	0730		8.11	2520	545	40	125	135	1444	1606	4431	9240	96	50	9.7
		11/20/76	1530		8.02	2480	550	45	109	90	1580	1688	4609	9463	104	54	5.0
		11/20/76	2330		7.99	2709	599	44	108	180	1411	1627	4520	9571	94	52	14.7
		11/21/76	0730		7.91	2640	621	40	117	90	1853	1961	4431	9792	120	50	11.6
		11/21/76	1530		8.10	2739	643	44	115	22	1592	1918	4609	10064	123	54	12.6
		11/21/76	2330		7.93	2510	626	42	114	67	1777	1857	4254	9390	113	50	12.6
		11/22/76	0730		7.81	2360	638	38	121	67	1923	2003	4520	9667	118	50	3.3
	2825	11/15/76	1930		4.49	2930	355	37	123	90	3279	3387	3722	10536	233	50	2.6
		11/15/76	2330		4.33	2849	401	498	121	655	1090	1876	5761	11375	81	51	-0.8
					7.95	2650	375	39	125	655	631	1417	3914	8389	48	51	16.7
					4.33	2949	401	38	121	655	334	1090	1676	6244	23	51	58.0
		11/16/76	0730		4.32	3019	460	41	127	995	2251	3445	4077	10570	160	49	3.5
		11/16/76	1530		4.37	2800	443	45	130	1221	2166	3631	3900	10705	152	52	-2.3
		11/16/76	2330		4.41	2899	447	43	130	995	2165	3359	4254	10933	153	49	-1.8
		11/17/76	0730		4.45	2600	437	43	122	1221	2166	3631	4254	10843	149	48	-14.6
		11/17/76	1530		4.57	2690	450	43	114	588	2713	3419	3634	10232	184	50	1.3
		11/17/76	2330		4.74	2899	474	40	102	972	2131	3297	4697	11315	149	51	-7.0
		11/18/76	0730		4.64	3720	559	40	112	904	1961	3046	5140	12436	145	48	11.8
		11/18/76	1730		4.56	3589	544	39	106	836	2085	3088	6027	13226	152	51	-2.6
		11/18/76	2330		4.37	4370	591	40	122	1017	2223	3443	6115	14478	169	50	10.1
		11/19/76	0930		4.41	3260	507	39	124	859	2600	3631	5140	12529	184	50	-5.4
		11/19/76	1530		4.39	3459	509	32	113	1153	2264	3648	5495	13025	165	52	-5.6
		11/19/76	2330		4.48	3199	585	34	102	1311	2162	3735	4786	12179	150	50	-0.4
		11/20/76	0730		4.50	2909	562	44	128	1402	1761	3443	4343	11149	121	49	1.2
		11/20/76	1530		4.65	2879	594	47	116	927	2619	3731	4963	12145	172	54	-10.2
		11/20/76	2330		4.66	2630	589	46	112	1379	1788	3443	4697	11241	117	53	-10.6
		11/21/76	0730		4.44	2960	604	42	115	1221	2657	4132	4343	11952	176	50	-3.1

LIQUID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	LIQUID FLAG	PH	CA++ PPM	MG++ PPM	NA+ PPM	K+ PPM	SO3= PPM	SO4= PPM	TOTAL SO4= PPM	CL- PPM	TOTAL DISSOL SOLIDS PPM	SULFATE SAT %	LIQ TEMP C	LIQ IONIC IMBAL %
617-2A	2825	11/21/76	1530		4.58	3080	676	40	112	1153	2431	3815	4609	12101	160	54	2.1
		11/21/76	2330		4.66	2800	641	40	111	995	2374	3568	4077	11038	153	51	3.9
		11/22/76	0730		4.57	2839	678	40	123	1334	2217	3818	4431	11662	143	48	-1.1

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
583-2A	2816	04/15/76	2330		32.60	20.20	5.15	30.40	5.64	16.4	6.02	5.97	17.0	1.53	1.34	12.6
		04/16/76	0330		29.80	22.60	7.45	35.70	3.34	13.7	4.95	5.04	20.9	1.19	1.17	1.8
		04/16/76	0730		30.90	17.60	9.00	31.00	5.68	13.3	4.69	4.91	29.0	1.42	1.33	6.0
		04/16/76	1130		30.70	20.60	6.95	32.70	5.40	15.7	5.63	5.71	21.3	1.34	1.30	7.0
		04/16/76	1530		30.20	20.10	8.28	33.40	5.22	15.1	5.27	5.47	24.8	1.29	1.28	0.5
		04/16/76	2330		28.70	14.20	10.65	28.40	6.16	13.3	5.02	5.43	37.5	1.42	1.39	1.6
		04/17/76	0330		30.00	17.20	14.80	36.30	4.51	13.5	3.77	4.52	40.8	1.18	1.23	-3.9
		04/17/76	0730		28.30	14.40	12.60	30.60	4.99	15.4	5.52	6.12	41.2	1.32	1.30	1.8
		04/17/76	1130		25.55	17.95	9.02	31.45	1.96	14.2	6.21	6.46	28.7	1.16	1.11	4.9
		04/17/76	1530		25.94	19.36	10.61	34.81	3.63	15.4	5.49	5.77	30.5	1.19	1.15	-0.2
					28.90	19.50	10.63	35.00	3.63	15.4	5.40	5.75	30.4	1.19	1.19	-0.3
		04/17/76	1930		28.30	18.10	9.68	32.30	3.57	16.6	6.34	6.70	30.0	1.25	1.20	4.0
		04/17/76	2330		26.80	13.90	10.25	28.10	4.34	14.7	6.06	6.50	38.6	1.34	1.28	5.9
		04/18/76	0730		27.20	20.90	9.48	35.60	1.18	15.3	6.06	6.31	26.6	1.09	1.06	2.8
		04/18/76	1130		25.60	18.20	9.05	31.80	1.96	14.2	6.21	6.42	28.5	1.15	1.11	3.2
		04/18/76	1530		26.20	16.30	11.03	31.40	1.81	13.2	5.51	5.90	35.1	1.19	1.10	7.2
		04/18/76	2330	SO2	27.60	13.10	15.13	31.50	3.41	14.4	5.12	5.87	48.0	1.25	1.20	4.3
		04/19/76	0730		27.60	19.30	9.28	33.40	3.07	13.7	5.34	5.58	27.8	1.18	1.17	1.1
		04/19/76	2330		30.20	19.30	11.48	35.60	3.90	15.5	5.02	5.44	32.2	1.21	1.20	1.0
		04/20/76	2330		29.40	18.40	8.80	31.80	6.32	16.2	5.76	6.01	27.7	1.32	1.36	-3.2
	2818	04/15/76	2330		22.10	11.50	6.43	20.80	3.95	40.5	22.09	22.73	30.9	1.51	1.35	12.9
		04/16/76	2330		27.90	17.10	6.63	28.00	5.88	30.5	12.71	12.96	23.7	1.42	1.38	2.9
		04/18/76	2330	SO2	28.30	13.50	13.53	30.40	4.29	41.3	14.98	16.68	44.5	1.33	1.26	5.4
583-2B	2816	04/22/76	0730		27.91	15.56	10.51	29.96	5.50	14.1	5.35	5.71	35.1	1.33	1.33	-0.3
		04/22/76	1130		28.40	15.40	10.15	29.40	5.11	12.8	4.91	5.24	34.5	1.38	1.32	4.6
		04/22/76	1530		30.90	15.30	7.68	26.80	8.49	14.4	5.20	5.43	28.5	1.64	1.59	3.9
		04/22/76	1930		31.70	14.30	8.43	26.30	10.17	15.8	5.28	5.59	32.0	1.72	1.70	1.0
		04/22/76	2330		28.50	14.70	10.53	28.90	8.31	14.8	5.29	5.52	36.4	1.41	1.52	-8.2
		04/23/76	0330		27.90	17.90	8.93	31.30	5.77	16.0	5.74	6.02	28.5	1.36	1.34	1.8
		04/23/76	0730		26.30	14.20	8.65	26.40	5.44	15.0	6.49	6.81	32.8	1.42	1.37	3.3
		04/23/76	1130		29.50	16.20	11.65	31.90	5.90	16.8	5.62	6.17	36.5	1.32	1.34	-1.2
		04/23/76	1530		30.80	19.50	10.83	35.20	5.09	17.7	5.55	5.98	30.8	1.25	1.26	-1.1
		04/23/76	1930		28.20	18.70	9.13	32.50	4.60	15.9	6.02	6.26	29.1	1.24	1.26	-1.5
		04/23/76	2330		26.30	16.00	8.90	28.90	3.68	15.7	6.74	7.05	30.8	1.30	1.24	4.2
		04/24/76	0330		25.30	14.20	9.75	27.50	5.00	15.0	6.39	6.79	35.5	1.34	1.33	0.6
		04/24/76	0730		25.10	10.90	7.98	21.60	7.15	16.2	7.57	7.92	36.9	1.66	1.60	3.4
		04/24/76	1130		26.00	13.90	8.23	25.60	4.16	14.8	6.81	7.06	32.1	1.45	1.30	10.6
		04/24/76	1530		27.30	15.80	6.95	26.70	5.12	16.9	7.36	7.58	26.0	1.46	1.35	7.6
		04/24/76	1930		26.70	15.30	5.68	24.80	4.63	17.4	8.22	8.30	22.9	1.54	1.34	12.8
		04/24/76	2330	TS	26.40	17.40	0.25	22.00	3.23	15.0	8.19	7.91	1.2	1.71	1.27	26.0
		04/25/76	0330	TS	28.40	14.50	2.38	20.50	5.06	14.3	7.21	7.10	11.6	1.90	1.45	26.7
		04/25/76	0730		27.50	14.50	9.98	28.10	4.89	15.0	6.02	6.46	35.5	1.40	1.32	6.1
		04/25/76	1130	X	14.76	13.75	-3.48	13.70	7.26	13.8	[illegible]	9.35	-25.4	1.54	1.76	-27.7
		04/25/76	1530													
		04/25/76	1930	X	17.76	18.16	-5.43	17.27	3.96	14.8	10.30	9.70	-31.4	1.47	1.42	3.5

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL Y
583-2B	2816	04/25/76	2330	X	17.62	19.71	-8.38	16.25	3.15	14.4	10.66	9.78	-51.6	1.55	1.35	12.6
		04/26/76	0730	TS	26.70	16.20	0.45	20.70	3.52	14.6	8.02	7.76	2.2	1.84	1.31	27.9
		04/26/76	1130		27.10	15.50	9.33	28.70	3.69				32.5	1.35	1.23	8.5
		04/26/76	1630	TS	30.70	19.22	2.60	26.60	4.01	14.0	6.26	6.09	9.8	1.65	1.27	22.7
		04/26/76	1930		26.20	16.80	10.70	31.70	3.63	15.0	6.02	6.40	33.8	1.18	1.21	-2.4
		04/26/76	2330		27.30	15.40	14.05	33.30	4.52	16.5	5.70	6.39	42.2	1.17	1.25	-5.5
		04/27/76	0730	TS	33.00	18.30	1.93	24.80	5.34	15.4	6.59	6.38	7.8	1.90	1.39	25.7
		04/27/76	0800													
		04/27/76	1130		30.40	18.00	10.70	34.20	5.42	14.7	4.74	5.15	31.7	1.27	1.29	-1.5
		04/27/76	1530		31.10	20.40	11.20	36.70	4.95	15.0	4.53	4.85	30.5	1.21	1.25	-2.9
		04/27/76	2330		29.60	16.20	10.45	30.70	6.05	15.4	5.56	5.96	34.6	1.33	1.36	-2.1
		04/28/76	0330		29.20	16.40	11.30	31.80	5.06	15.8	5.53	6.01	35.5	1.31	1.29	1.6
		04/28/76	0730		29.50	19.90	8.83	33.70	4.87	15.2	5.41	5.61	26.2	1.25	1.26	-1.1
		04/28/76	1030		31.10	15.70	15.33	35.20	4.28	12.4	3.55	4.14	43.5	1.26	1.22	3.2
		04/28/76	1530		34.20	17.40	8.95	30.70	9.09	14.5	4.13	4.40	29.2	1.59	1.54	7.7
		04/28/76	2330	SO2	30.90	13.40	15.45	36.20	4.71	16.3	4.02	5.14	53.7	1.22	1.24	-1.5
		04/29/76	0730	SO2	27.30	11.50	11.93	26.30	5.75	13.3	5.26	5.79	45.4	1.48	1.40	5.7
		04/29/76	1530		29.40	20.60	10.15	35.90	2.67	14.4	5.09	5.35	28.3	1.17	1.14	2.9
		04/29/76	2330		28.60	19.70	10.58	35.20	3.46	7.7	2.73	2.90	30.1	1.16	1.18	-1.6
		04/30/76	0730		28.20	20.00	9.40	34.40	5.06	10.2	5.07	5.30	27.3	1.17	1.27	-8.3
		04/30/76	1530		31.10	22.80	10.10	38.60	5.15	13.6	3.96	4.20	26.2	1.15	1.24	-3.0
		04/30/76	2330		30.60	19.80	13.95	38.70	3.09	14.5	4.21	4.76	36.1	1.13	1.14	-1.4
		05/01/76	0730		25.50	12.80	12.00	28.00	3.98	13.2	5.54	6.04	42.9	1.30	1.26	3.2
	2821	04/22/76	0730		26.30	14.50	8.19	26.30	5.66	56.1	24.45	25.45	31.1	1.43	1.39	2.5
		04/23/76	0730		23.70	14.90	5.38	24.00	5.39	56.4	28.32	23.56	22.4	1.41	1.41	3.1
		04/24/76	0730		23.40	9.80	8.85	21.10	6.76	67.7	32.77	34.66	42.0	1.59	1.58	0.0
		04/25/76	0730	X	13.64	13.03	-1.99	14.29	6.21				-14.0	1.34	1.79	-31.4
		04/27/76	0730	CA	48.70	17.80	0.45	22.70	5.94	54.6		14.90	2.0	3.06	1.48	51.8
		04/28/76	0730		27.50	16.30	8.93	29.30	5.33	61.2		25.06	30.5	1.34	1.39	-4.0
		04/30/76	1530		28.30	19.00	9.35	33.10	3.97	54.6		21.50	28.3	1.22	1.22	3.2
584-2A	2816	05/04/76	0730	X	37.60	7.60	9.20	18.70	13.70	16.4	3.89	4.41	49.2	2.87	2.82	1.8
		05/04/76	1530		34.20	17.00	8.55	29.80	9.18	15.6	4.62	4.85	28.7	1.64	1.56	4.8
		05/04/76	2330	CO2	34.40	20.50	3.98	29.60	4.60	15.5	5.76	5.66	13.4	1.66	1.28	22.7
		05/05/76	0730		33.00	22.80	6.10	34.60	6.51	17.7	5.58	5.59	17.6	1.35	1.74	1.4
		05/05/76	1530		33.00	15.50	3.03	22.40	13.44	15.7	5.59	5.50	13.5	2.10	2.09	3.0
		05/05/76	2330		29.00	14.50	2.78	20.90	9.79	15.6	6.93	6.85	13.3	1.98	1.95	6.5
		05/06/76	0730		30.40	17.10	3.53	24.90	8.49	15.7	6.42	6.32	14.2	1.74	1.63	6.2
		05/07/76	0730		31.30	16.20	5.85	26.10	10.02	15.8	5.71	5.79	22.4	1.71	1.70	0.8
		05/07/76	1530		31.60	21.30	9.76	36.40	4.62	15.5	5.10	5.49	26.9	1.24	1.23	0.7
		05/07/76	2330		33.60	20.40	5.10	30.60	9.71	15.2	4.80	4.74	16.7	1.57	1.58	-0.6
		05/08/76	0730		33.50	21.40	4.75	31.50	8.75	15.7	5.05	4.96	15.1	1.52	1.51	0.9
		05/08/76	1530		33.70	18.40	7.93	30.90	8.25	14.5	4.43	4.66	25.6	1.54	1.49	7.4
		05/08/76	2330		32.30	21.50	4.93	31.80	8.41	14.9	4.37	4.90	15.5	1.45	1.48	-2.1
		05/09/76	0730		34.70	24.50	4.78	35.40	6.81	16.8	5.07	4.91	13.5	1.40	1.35	7.5
		05/09/76	1530		33.50	27.40	5.96	40.20	5.28	17.2	4.90	4.79	14.8	1.19	1.24	-4.1

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
584-2A	2816	05/09/76	2330		32.40	23.90	6.23	36.10	5.06	14.1	4.59	4.57	17.8	1.28	1.25	2.1
		05/10/76	0730		32.50	21.30	9.88	36.50	5.04	14.5	4.30	4.54	27.1	1.27	1.25	1.6
		05/10/76	1300													
		05/10/76	1530		30.50	18.80	5.00	28.50	5.77	15.4	6.56	5.15	17.6	1.53	1.37	10.4
		05/11/76	0730		32.10	23.30	4.78	33.90	6.54	14.2	4.36	4.73	14.1	1.35	1.35	0.1
		05/11/76	1530		31.30	20.40	5.70	31.20	7.09	13.7	4.34	4.86	13.3	1.43	1.41	1.3
		05/11/76	2330		31.10	21.20	7.70	34.20	7.41	13.8	4.40	4.50	22.5	1.30	1.39	-7.4
		05/12/76	0730		29.00	24.80	3.50	34.50	2.39	17.9	7.69	7.35	10.2	1.16	1.13	2.8
		05/12/76	0845													
		05/12/76	1530		29.50	23.30	2.73	32.60	4.78	17.2	7.02	6.72	8.4	1.29	1.27	1.9
		05/12/76	2330		33.40	21.80	6.95	34.10	5.98	14.4	4.42	4.46	20.1	1.40	1.37	1.9
		05/13/76	0730		30.00	21.20	5.20	31.70	6.77	13.0	5.15	4.79	16.4	1.35	1.39	-0.8
		05/13/76	1300													
		05/13/76	1530		29.10	17.80	6.25	28.50	5.61	14.4	5.94	5.94	21.9	1.46	1.36	6.8
		05/13/76	2330		30.50	17.40	4.95	26.70	7.48	17.4	6.32	6.90	18.5	1.63	1.51	7.4
		05/14/76	0730		33.70	19.90	0.83	25.70	12.01	14.3	5.16	4.36	3.2	1.95	1.85	0.0
	2818	05/07/76	2330		30.40	17.00	4.85	26.10	10.51	32.0	11.33	11.92	18.6	1.65	1.73	-4.2
585-2A	2816	05/14/76	1530		30.40	15.60	6.50	26.00	8.61	14.4	5.50	5.60	25.9	1.67	1.60	4.0
		05/14/76	2330		28.90	13.90	9.45	26.70	6.32	14.6	5.68	6.03	35.4	1.54	1.43	7.1
		05/15/76	0730		29.40	20.90	7.18	33.30	4.41	16.3	6.11	6.21	21.6	1.26	1.24	1.5
		05/15/76	1530		30.70	21.30	6.38	33.00	5.33	14.3	5.16	5.19	19.3	1.33	1.29	2.6
		05/15/76	2330		31.90	18.20	7.65	30.40	5.50	12.0	4.27	4.41	25.2	1.59	1.33	11.3
		05/16/76	0730	TS	34.30	16.20	18.35	38.60	7.24	14.1	2.51	3.37	47.5	1.27	1.34	-5.7
		05/16/76	1530		27.90	16.90	3.19	24.30	7.55	13.4	6.07	5.96	13.1	1.64	1.57	4.5
		05/16/76	2330		30.80	17.10	11.43	32.60	6.27	13.1	4.13	4.51	34.8	1.34	1.35	-0.5
		05/17/76	0730		28.40	20.30	7.63	33.00	6.34	15.2	5.51	5.67	23.1	1.23	1.35	-0.8
		05/17/76	1530		33.40	19.40	7.75	32.00	9.54	15.3	4.42	4.58	24.2	1.49	1.54	-3.5
		05/17/76	2330		33.20	20.00	6.60	31.60	3.25	14.8	4.63	4.73	20.9	1.50	1.47	1.7
		05/18/76	0730		30.10	20.40	5.90	31.40	6.82	14.7	5.38	5.41	18.8	1.37	1.48	-1.9
		05/18/76	1530		29.70	14.70	8.13	26.50	7.93	15.3	5.76	6.05	30.7	1.60	1.54	3.5
		05/18/76	2330		30.20	15.60	8.70	28.20	8.48	14.1	4.95	5.22	30.9	1.53	1.55	-1.2
		05/19/76	0730		32.00	17.90	10.03	32.40	7.53	14.5	4.38	4.72	31.0	1.41	1.42	-0.9
		05/19/76	1530		31.90	14.90	9.98	28.60	9.02	14.0	4.43	4.79	34.9	1.59	1.57	1.2
		05/19/76	2330	SO2	33.00	11.90	10.43	25.30	10.93	15.2	4.54	5.14	41.2	1.86	1.78	4.5
		05/20/76	0730		28.10	19.40	4.25	28.50	5.72	15.1	6.52	6.42	14.9	1.41	1.37	3.0
	2818	05/14/76	2330		30.30	20.70	4.83	30.70	6.76	32.8	12.41	12.27	15.7	1.41	1.40	0.6
		05/17/76	2330		29.00	18.30	6.13	29.00	6.76	35.6	14.04	14.17	21.1	1.43	1.42	0.2
586-2A	2816	05/20/76	1600		28.70	16.20	4.75	25.00	7.70	15.2	6.49	6.48	19.0	1.64	1.56	4.8
		05/20/76	2330		31.30	20.80	7.10	33.10	8.48	15.9	5.05	5.14	21.5	1.35	1.47	-8.6
		05/21/76	0730		30.70	18.60	11.25	34.50	6.16	14.0	4.30	4.66	32.6	1.27	1.32	-4.3
		05/21/76	1530		28.90	18.30	5.63	28.50	6.44	14.6	5.91	5.95	19.7	1.45	1.41	2.5
		05/21/76	2330		31.70	20.20	9.55	34.80	6.60	12.8	3.85	4.09	27.5	1.30	1.35	-3.4
		05/22/76	0730		24.50	17.40	2.35	24.10	6.16	14.1	7.15	6.99	9.3	1.45	1.46	-2.9
		05/22/76	1530		28.00	14.50	0.98	19.10	9.79	13.6	6.53	6.36	5.1	2.09	1.93	7.7
		05/22/76	2330		30.00	20.60	6.65	32.40	5.59	15.1	5.54	5.61	20.5	1.32	1.31	0.6

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
586-2A	2816	05/23/76	0730		29.90	17.10	11.23	32.60	5.72	15.8	5.22	5.70	34.4	1.31	1.32	-0.7
		05/23/76	1530		30.50	20.00	5.90	30.90	5.77	15.2	5.72	5.75	19.1	1.41	1.34	4.0
		05/23/76	2330		31.30	17.60	11.90	33.90	5.98	14.8	4.49	4.92	35.1	1.32	1.32	-0.2
		05/24/76	0730		29.60	21.00	6.45	32.70	5.17	14.2	5.49	5.51	19.7	1.25	1.29	-3.1
		05/24/76	1600		28.90	18.30	6.33	29.20	4.51	13.7	5.70	5.76	21.7	1.41	1.28	9.0
		05/24/76	2330		31.10	18.70	11.63	35.00	5.86	14.8	4.44	4.84	33.2	1.27	1.30	-2.4
		05/25/76	0445		31.00	21.30	8.18	34.90	6.07	14.8	4.81	4.95	23.5	1.27	1.32	-3.6
	2818	05/21/76	2330		29.00	17.70	7.66	29.80	6.54	36.7	13.59	14.34	25.6	1.39	1.40	-0.7
		05/24/76	2330	CA	26.20	18.40	7.40	30.40	6.18	35.1	14.70	15.10	24.4	1.23	1.37	-11.3
587-2A	2816	05/31/76	1530		31.30	21.10	8.83	35.20	6.02	12.7	4.00	4.16	25.1	1.27	1.31	-3.3
		05/31/76	2330		25.60	13.40	3.65	20.40	7.97	9.2	4.54	4.54	17.9	1.79	1.71	4.5
		06/01/76	0730	X	26.60	8.70	0.03	10.90	12.04	9.1	4.90	4.79	0.2	3.48	3.01	13.6
		06/01/76	1530		29.90	18.50	7.18	30.30	6.79	11.0	4.05	4.14	23.7	1.41	1.41	0.1
		06/01/76	2330		31.30	17.40	3.75	25.50	9.40	9.7	3.77	3.70	14.7	1.75	1.67	4.7
		06/02/76	0730		28.10	13.60	3.10	20.10	10.89	11.0	4.90	4.87	15.4	2.00	1.39	0.5
		06/02/76	0800													
		06/02/76	1530		28.10	14.10	3.08	20.70	10.62	11.5	5.13	5.07	14.9	1.94	1.93	0.2
		06/02/76	2330		28.00	12.70	4.43	20.30	10.69	9.5	4.15	4.18	21.8	1.37	1.38	-2.3
		06/03/76	0730		31.10	18.20	4.15	26.90	8.60	9.9	3.78	3.76	15.4	1.65	1.58	4.2
		06/03/76	1530		32.30	19.60	7.70	32.20	6.35	10.5	3.49	3.58	23.9	1.43	1.36	5.1
		06/03/76	2300		32.50	13.80	7.40	30.90	7.23	8.6	2.85	2.93	24.0	1.50	1.43	5.1
		06/05/76	1530	TS	31.80	14.20	8.15	25.90	6.71	9.9	3.59	3.87	31.5	1.75	1.47	16.1
		06/05/76	2330	TS	29.40	13.40	4.55	21.30	8.58	6.9	3.02	3.04	21.4	1.97	1.73	12.1
		06/06/76	0730		30.60	12.70	9.63	25.50	11.07	6.9	2.29	2.48	37.8	1.71	1.79	-4.5
		06/06/76	1530		31.70	17.00	5.85	27.10	7.72	8.7	3.23	3.23	21.6	1.67	1.52	9.1
		06/06/76	2330		28.40	15.60	8.30	27.60	5.17	8.0	3.28	3.40	29.9	1.46	1.34	8.2
		06/07/76	0730	TS	29.60	7.40	13.45	22.70	6.94	8.4	3.16	3.58	59.3	1.66	1.56	16.4
		06/07/76	1530		32.90	21.20	11.40	37.90	7.27	9.3	2.30	2.57	30.1	1.24	1.35	-3.9
		06/07/76	2330		31.00	16.70	10.33	31.20	5.12	8.7	2.99	3.21	33.1	1.42	1.30	3.5
		06/08/76	0730		32.40	18.60	10.60	34.30	6.26	5.3	2.41	2.67	31.5	1.35	1.33	1.2
		06/08/76	1530		28.00	16.50	4.98	25.60	6.48	7.3	3.43	3.44	19.4	1.56	1.46	6.5
		06/08/76	2330		30.80	16.60	10.25	31.00	6.92	8.4	2.77	2.96	33.1	1.42	1.41	0.9
		06/09/76	0730	TS	33.50	6.30	11.33	19.20	7.20	9.1	3.38	3.79	59.0	2.49	1.68	32.5
		06/09/76	1530		31.10	17.70	8.08	30.20	7.96	8.6	2.90	3.02	26.8	1.47	1.48	-0.6
		06/09/76	2330		27.20	12.10	12.68	27.80	7.26	6.5	2.95	3.30	45.6	1.50	1.48	1.6
		06/10/76	0730		26.80	10.50	10.78	23.90	5.99	9.7	3.69	4.00	45.1	1.60	1.46	7.1
		06/10/76	1530		31.90	18.30	5.03	27.90	7.70	8.4	3.10	3.11	10.0	1.63	1.50	8.0
		06/10/76	2330	TS	32.80	9.80	7.15	19.40	10.14	7.1	2.69	2.65	36.9	2.41	1.95	19.2
		06/11/76	0730	X	38.70	3.70	10.98	15.60	20.85	9.1	1.94	2.35	70.4	3.54	3.43	3.1
		06/11/76	1530		29.60	16.30	7.03	27.40	9.30	10.5	3.86	3.97	25.7	1.64	1.62	-4.9
		06/11/76	2330		29.30	18.00	7.89	30.30	7.73	8.2	2.94	3.05	25.8	1.38	1.46	-6.1
		06/12/76	0730		29.30	18.90	6.49	30.10	8.05	9.1	3.34	3.39	21.5	1.39	1.49	-7.0
		06/12/76	1530		31.70	15.20	5.65	25.90	12.29	8.3	2.75	2.84	21.8	1.75	1.66	-6.6
		06/12/76	2330		33.10	16.70	9.83	30.70	11.39	9.4	2.49	2.72	32.0	1.54	1.67	-8.5
		06/13/76	0730		33.80	15.90	9.23	29.10	8.53	9.3	2.82	3.03	31.7	1.65	1.53	7.5

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
587-2A	2816	06/13/76	1530		31.90	13.30	10.28	26.90	10.31	7.8	2.43	2.67	38.2	1.69	1.70	-0.3
		06/13/76	2330		33.90	16.20	11.35	31.60	12.66	9.8	2.24	2.54	35.9	1.53	1.73	-12.9
		06/14/76	0530	SO2	32.80	9.60	13.70	25.90	11.45	7.9	2.13	2.54	53.7	1.31	1.90	0.5
	2818	05/31/76	2330		27.20	16.30	6.23	26.60	6.93	24.0	10.25	10.40	23.4	1.46	1.47	-1.0
		06/07/76	2330		30.30	15.60	5.90	25.40	6.97	27.2	10.95	11.21	23.2	1.70	1.50	12.0
		06/11/76	2330		27.50	12.40	8.90	24.40	10.06	32.3	12.47	13.29	36.5	1.61	1.75	-8.8
	2821	06/07/76	1530	TS	29.40	16.40	11.80	32.30	8.65	51.3		17.31	35.5	1.30	1.49	-14.4
		06/11/76	1530		25.00	10.80	8.00	21.50	6.92	54.1		26.66	37.2	1.66	1.59	4.5
588-2A	2816	06/17/76	0730		31.90	14.20	9.55	27.30	10.25	15.1	4.60	5.15	35.0	1.67	1.69	-4.7
		06/17/76	1530		30.40	6.00	7.40	17.40	12.11	14.4	5.70	6.04	42.5	2.49	2.27	5.1
		06/17/76	2330		36.50	10.50	9.28	22.40	13.69	15.0	4.34	4.81	41.4	2.33	2.11	3.2
		06/18/76	0730		31.02	15.30	5.85	24.97	9.43	14.1	4.81	5.42	23.4	1.77	1.69	4.9
		06/18/76	1530		31.10	12.00	5.70	20.70	11.16	13.9	5.41	5.57	27.5	2.14	1.98	7.7
		06/18/76	2330		29.10	11.90	7.55	22.30	9.83	14.2	5.73	6.07	33.9	1.96	1.72	7.7
		06/19/76	0730		29.[illegible]	10.00	5.70	18.20	12.55	13.7	5.67	5.86	31.3	2.27	2.25	0.9
		06/19/76	1530		32.20	11.10	6.73	20.60	12.27	15.1	5.40	5.69	32.7	2.23	2.08	6.6
		06/19/76	2330		30.70	7.20	8.10	17.10	12.65	14.6	5.55	6.04	47.4	2.56	2.35	8.5
		06/20/76	0730	X	36.23	2.64	6.14	9.44	23.45	13.7	2.99	4.73	65.0	5.48	4.34	9.8
				X	35.51	2.71	5.64	9.03	32.12	13.7	2.98	3.29	62.5	5.61	7.47	-33.1
		06/20/76	1530		34.80	10.70	4.93	18.30	15.40	13.9	4.64	4.75	26.9	2.71	2.53	6.8
		06/20/76	2330		29.10	11.20	4.10	18.10	13.20	12.9	5.40	5.47	22.7	2.30	2.33	-1.4
	2821	06/18/76	0730		30.50	10.20	11.35	24.10	9.13	58.7		22.73	47.1	1.91	1.69	4.5
		06/19/76	0730		29.00	8.40	8.60	19.10	11.27	66.5		28.42	45.0	2.17	2.07	4.3
589-2A	2816	06/21/76	1530	CA	28.03	8.82	6.59	17.61	10.97	14.6	5.74	6.65	37.4	2.27	2.13	6.1
		06/21/76	2330		37.20	12.30	8.25	23.60	14.59	16.5	4.22	4.60	34.9	2.25	2.12	7.6
		06/22/76	0730		32.40	15.50	4.03	23.40	11.23	15.1	5.57	5.56	17.2	1.98	1.87	5.2
		06/23/76	1530		32.10	12.70	6.33	22.20	12.87	14.9	5.10	5.36	25.5	2.06	2.05	0.5
		06/23/76	2330		31.70	18.50	8.15	31.40	6.98	14.2	4.72	4.91	26.0	1.44	1.40	2.6
		06/24/76	0730		30.60	14.80	4.50	23.00	9.48	15.8	6.36	6.42	19.6	1.90	1.75	7.9
		06/24/76	1530		31.40	21.60	7.70	34.70	5.99	15.4	4.99	5.13	22.2	1.29	1.31	-1.7
		06/24/76	2330		29.90	19.00	7.45	31.20	5.66	15.9	5.90	6.04	23.9	1.37	1.33	2.8
		06/25/76	2330		28.40	19.60	8.50	33.00	3.63	14.0	5.38	5.56	25.9	1.23	1.20	2.3
		06/26/76	0730		25.80	19.50	5.15	29.50	4.32	13.7	6.22	6.20	17.4	1.25	1.27	-1.4
		06/26/76	1530		28.90	24.20	5.65	35.90	2.53	14.5	5.73	5.64	15.6	1.15	1.12	2.7
		06/26/76	2330		26.70	20.00	7.60	32.60	3.30	15.4	6.40	6.53	23.3	1.17	1.10	-1.3
		06/27/76	0730		29.10	23.10	7.23	36.10	3.09	14.3	5.33	5.36	20.0	1.15	1.16	-0.4
		06/27/76	1530		26.90	20.40	3.70	29.20	3.38	14.4	6.83	5.70	12.7	1.27	1.21	4.8
		06/27/76	2330		27.90	19.60	7.60	32.10	4.07	14.3	5.69	5.24	23.7	1.24	1.23	0.8
		06/28/76	0730		27.00	18.10	6.78	29.40	5.67	14.4	5.97	5.11	23.1	1.31	1.35	-7.0
		06/28/76	1530		27.90	20.20	6.95	32.10	4.51	13.9	5.53	5.64	21.4	1.24	1.26	-1.2
		06/28/76	2330		27.40	17.80	4.75	27.00	6.19	14.0	6.17	6.14	17.6	1.45	1.42	2.2
		06/29/76	0730		26.70	18.40	1.40	24.40	6.72	14.5	6.90	6.69	5.8	1.56	1.50	3.9
		06/29/76	1530		26.60	18.30	1.65	24.50	6.92	13.4	6.44	6.24	6.6	1.55	1.51	2.3
		06/29/76	2330		31.60	22.90	6.08	34.70	4.47	15.4	5.40	5.34	17.5	1.30	1.33	5.1
		06/30/76	0730		28.10	19.70	1.38	26.00	5.70	15.8	7.67	7.41	5.3	1.54	1.47	4.8

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
599-2A	2816	06/30/76	1530		29.20	24.50	4.08	34.70	3.51	15.5	6.10	6.09	11.8	1.20	1.19	1.4
		06/30/76	2330		29.40	21.00	5.75	32.00	4.40	15.3	6.05	6.04	18.0	1.31	1.25	4.7
		07/01/76	0500		26.30	15.00	2.55	21.30	3.64	15.4	7.43	7.32	12.0	1.76	1.74	1.4
	2821	06/28/76	1530		23.50	16.20	5.35	25.60	5.25	59.0		29.32	20.9	1.31	1.37	-4.8
601-2A	2816	07/02/76	0730		24.10	23.70	5.18	34.80	0.24	8.9	4.21	4.16	14.9	0.99	1.01	-2.4
		07/02/76	1530		28.30	23.10	8.53	37.40	0.16	8.2	3.19	3.27	22.8	1.08	1.01	6.7
		07/04/76	0730		26.90	23.10	5.73	34.60	0.57	8.8	3.84	3.85	16.6	1.11	1.03	7.2
		07/06/76	1530		27.80	22.60	8.45	36.70	1.15	8.9	3.42	3.52	23.0	1.08	1.06	3.3
		07/06/76	2330	TS	26.80	24.30	1.83	32.20	1.15	7.8	3.77	3.58	5.7	1.19	1.06	10.4
		07/07/76	0730		27.40	23.00	7.85	36.60	1.98	8.0	3.15	3.19	21.5	1.07	1.10	-2.8
		07/07/76	1530		28.80	23.90	7.13	37.00	1.04	8.5	3.29	3.33	19.3	1.11	1.05	5.4
		07/07/76	2330		29.40	25.50	4.03	35.90	0.77	8.3	3.46	3.35	11.2	1.17	1.04	11.1
		07/08/76	0730		26.40	23.60	5.40	34.90	0.16	8.6	3.86	3.82	15.5	1.08	1.01	6.5
		07/08/76	1530		30.80	23.30	9.78	38.90	1.04	8.1	2.72	2.94	25.1	1.13	1.05	7.2
		07/08/76	2330		28.64	26.06	4.22	36.79	0.27	8.3	3.50	3.39	11.5	1.11	1.01	8.8
		07/09/76	0730		25.40	23.20	5.20	34.20	0.26	8.1	3.75	3.72	15.2	1.06	1.01	4.4
		07/09/76	1530		27.30	26.80	4.71	38.20	0.80	8.2	3.41	3.31	12.3	1.02	1.04	-1.7
		07/09/76	2330		23.70	22.50	2.38	30.50	0.71	8.3	4.29	4.21	7.9	1.11	1.04	6.0
		07/10/76	0730		20.70	20.00	4.00	29.00	0.56	8.3	4.60	4.54	13.8	1.02	1.04	-1.6
		07/10/76	1530		25.50	25.00	6.96	38.20	1.45	8.3	3.31	3.33	16.2	0.99	1.07	-7.9
		07/10/76	2330		23.60	21.80	2.85	30.10	0.99	9.0	4.71	4.57	9.5	1.12	1.06	5.3
		07/11/76	0730		23.50	21.40	5.25	32.00	0.93	7.6	3.76	3.72	16.4	1.05	1.05	-0.4
		07/11/76	1530		22.20	20.00	4.90	29.90	0.30	8.0	4.24	4.21	16.4	1.06	1.02	3.9
		07/11/76	2330		23.10	21.50	3.43	30.30	0.64	8.2	4.33	4.21	11.3	1.09	1.04	4.6
		07/12/76	0530		25.20	23.20	4.90	33.90	0.71	7.3	3.41	3.36	14.5	1.06	1.04	2.2
	2821	07/02/76	1530		27.10	21.30	9.86	36.50	0.33	60.0		24.84	27.1	1.06	1.02	4.1
		07/06/76	1530		23.00	20.50	4.79	30.40	0.71	56.0		26.57	15.7	1.08	1.04	3.5
		07/07/76	1530		26.60	21.40	6.55	33.30	0.71				19.7	1.14	1.04	3.9
		07/08/76	1530		25.70	24.10	4.18	34.30	0.82	54.0		24.41	12.2	1.07	1.04	2.4
		07/09/76	1530		24.30	23.30	3.88	33.00	0.65	57.0		27.29	11.8	1.05	1.04	1.5
		07/10/76	1530		23.60	23.20	3.70	32.70	0.80	58.0		28.25	11.3	1.03	1.04	-1.4
		07/11/76	1530		23.10	20.40	7.80	33.30	0.25	60.0		29.07	23.4	0.99	1.01	-2.4
602-2A	2816	07/12/76	2330		24.70	23.90	2.73	32.60	0.33	16.3	8.18	7.85	8.4	1.08	1.02	5.8
		07/13/76	0730		27.00	25.60	4.71	36.70	0.79	14.8	6.39	6.20	12.8	1.05	1.04	1.1
		07/13/76	1530		28.10	26.20	7.76	40.50	0.64	15.5	5.79	5.78	19.1	0.99	1.03	-3.9
		07/13/76	2330		27.60	23.40	9.65	38.90	0.29	14.8	5.69	5.87	24.8	0.99	1.01	-2.3
		07/14/76	0730		27.00	23.90	9.43	39.30	0.93	8.7	3.24	3.37	24.0	0.98	1.04	-6.3
		07/14/76	1330													
		07/14/76	1530		26.00	24.40	7.80	38.30	0.59	14.7	6.04	6.06	20.4	0.97	1.03	-6.1
		07/14/76	2330		24.40	23.50	6.13	35.50	0.65	15.3	5.94	5.93	17.3	0.98	1.03	-5.3
		07/15/76	0730		24.80	24.00	3.40	33.40	1.48	15.3	7.28	7.09	10.2	1.06	1.08	-1.9
		07/15/76	0800													
		07/15/76	1530		26.70	25.00	3.06	34.30	0.39	15.3	7.12	6.86	8.9	1.11	1.02	8.2
		07/15/76	2330		23.80	21.30	5.48	32.10	0.43	14.4	7.10	7.05	17.1	1.06	1.03	2.9
		07/16/76	0730		27.30	22.80	7.90	36.40	0.60	15.0	6.10	6.21	21.7	1.07	1.03	3.6

SOLID ANALYSES

RUN NO.	ANALY TICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXI DAT ION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
602-2A	2816	07/16/76	1530		25.60	24.10	1.98	32.10	1.26	15.1	7.45	7.11	6.2	1.14	1.07	5.9
		07/16/76	2330		23.30	24.10	0.98	31.10	0.70	15.0	8.04	7.64	3.2	1.07	1.04	2.7
		07/17/76	0730		25.60	26.30	0.93	33.80	0.93	14.9	7.31	6.89	2.8	1.08	1.05	2.9
		07/17/76	1530		25.63	26.78	0.02	33.49	0.79	15.1	7.54	7.03	0.1	1.10	1.04	5.3
		07/17/76	2330		29.30	27.20	6.01	40.00	0.83	15.5	5.99	5.84	15.0	1.01	1.04	-2.7
		07/18/76	0730		25.00	23.10	3.33	32.20	0.66	14.5	7.17	6.95	10.3	1.11	1.04	6.4
	2821	07/13/76	1530		25.00	23.90	3.83	33.70	0.54	59.0		27.11	11.4	1.56	1.03	2.8
		07/14/76	1530		25.30	23.50	2.83	32.20	0.56	57.0		27.25	8.8	1.12	1.03	8.0
		07/15/76	1530		24.30	22.20	5.65	33.40	0.32	60.0		29.52	16.9	1.04	1.02	2.0
		07/16/76	1530		23.70	22.50	0.54	28.70	1.48	55.0		30.01	2.0	1.18	1.09	7.2
		07/17/76	1530		23.30	23.60	0.50	30.00	1.10	59.0		30.39	1.7	1.11	1.07	7.8
603-2A	2816	07/20/76	0730		22.80	20.50	2.68	28.30	3.52	8.6	4.45	4.32	9.5	1.15	1.25	-8.3
		07/20/76	1530		20.90	17.90	3.53	25.90	0.80	8.2	4.71	4.65	13.6	1.15	1.06	8.7
		07/20/76	2330		23.10	19.00	10.65	34.40	0.16	7.7	3.45	3.67	31.0	0.95	1.01	-5.2
					21.68	18.64	3.00	26.30	0.66				11.4	1.19	1.05	11.1
		07/21/76	0730		18.50	17.90	3.63	25.00	0.49	8.6	5.13	5.11	14.0	1.02	1.03	-1.3
		07/21/76	1530		21.60	19.20	6.95	29.70	0.49	8.7	4.53	4.59	23.4	1.04	1.03	0.6
		07/21/76	2330		22.40	22.60	4.35	32.60	0.38	8.8	4.47	4.42	13.4	0.98	1.02	-4.1
		07/22/76	0730		23.30	22.50	4.78	32.90	0.40	8.0	3.97	3.92	14.5	1.01	1.02	-1.1
		07/22/76	1530		23.70	23.10	3.63	32.50	0.32	9.3	4.68	4.59	11.2	1.04	1.02	2.2
					23.59	23.16	8.72	37.67	0.49				23.2	0.89	1.02	-14.5
					23.59	23.16	8.41	37.36	0.49				22.5	0.90	1.02	-17.5
		07/22/76	2330		26.50	24.00	4.70	34.70	0.05	7.2	3.28	3.22	13.6	1.09	1.00	4.6
		07/23/76	0730		25.20	22.10	9.08	36.70	0.36	7.6	3.22	3.29	24.7	0.99	1.02	-3.5
		07/23/76	1530		25.90	24.40	5.70	36.20	0.43	7.4	3.17	3.15	15.8	1.06	1.02	3.7
		07/23/76	2330		25.70	21.80	10.55	38.20	0.60	8.2	3.18	3.36	29.7	0.96	1.03	-7.1
		07/24/76	0730		24.20	21.00	6.35	32.60	0.19	8.1	3.90	3.91	19.5	1.06	1.01	4.6
		07/24/76	1530		23.50	22.20	6.15	33.90	0.31	7.4	3.56	3.54	18.2	0.99	1.02	-2.7
		07/24/76	2330		25.00	21.80	6.45	33.70	0.49	8.5	3.89	3.93	19.2	1.06	1.03	3.1
		07/25/76	0730		24.10	21.20	7.60	34.10	0.31	7.7	3.52	3.60	22.3	1.01	1.02	-0.8
		07/25/76	1530		23.60	20.90	9.68	35.80	0.37	7.6	3.32	3.45	27.0	0.94	1.02	-8.3
		07/25/76	2330		25.60	23.50	6.43	35.80	0.66	7.7	3.39	3.37	18.0	1.02	1.03	-1.2
		07/26/76	0730		24.00	21.60	5.90	32.90	0.21	7.6	3.65	3.67	17.9	1.04	1.01	2.9
		07/26/76	1530		22.00	22.60	5.55	33.80	0.12	8.1	4.04	4.07	16.4	0.93	1.01	-8.7
	2821	07/20/76	1530		20.30	16.80	6.30	27.30	0.73	62.0		34.64	23.1	1.06	1.05	1.2
		07/21/76	1530		20.50	17.10	7.33	28.70	0.55	61.0		33.26	25.5	1.02	1.03	-1.5
		07/22/76	1530		22.40	22.20	2.15	29.90	0.42	63.0		33.29	7.2	1.07	1.03	4.1
		07/23/76	1530		23.10	23.60	5.60	35.10	0.14	53.0		27.59	16.0	0.94	1.01	-7.2
		07/24/76	1530		21.70	21.50	5.43	32.30	0.17	59.0		30.21	16.8	0.95	1.01	-5.3
		07/25/76	1530		22.20	19.60	7.95	32.70	0.58	59.0		28.69	24.3	0.97	1.03	-6.5
		07/26/76	1530		22.00	22.60	3.45	31.70	0.11	62.0		32.14	10.9	0.99	1.01	-1.6
604-2A	2816	07/28/76	2330		23.80	21.30	6.93	33.60	0.23	7.1	3.35	3.39	20.8	1.01	1.01	-0.1
		07/29/76	0730		23.10	18.70	7.13	30.50	0.05	7.9	3.99	4.03	23.4	1.03	1.00	7.2
		07/29/76	1530													
		07/29/76	2330		22.60	15.20	10.60	29.60	0.15	7.1	3.45	3.65	35.8	1.09	1.01	7.4

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
604-2A	2816	07/30/76	0730		23.40	20.30	7.03	32.40	1.10	7.5	3.55	3.61	21.7	1.03	1.06	-3.0
		07/30/76	1500		25.00	20.30	9.63	35.00	0.08	7.8	3.36	3.51	27.5	1.02	1.00	1.5
		07/30/76	2330		21.50	17.10	7.63	29.00	0.15	7.9	4.15	4.24	26.3	1.06	1.01	4.5
		07/31/76	0730		22.50	16.00	10.00	30.00	0.33	7.4	3.63	3.79	33.3	1.07	1.02	4.7
		07/31/76	1530		23.50	17.70	13.18	35.30	0.38	8.3	3.45	3.76	37.3	0.95	1.02	-7.3
		07/31/76	2330		24.20	18.50	9.10	32.60	0.18	7.2	3.32	3.44	27.9	1.06	1.01	4.7
		08/01/76	0730		23.20	17.50	5.33	31.20	0.27	7.5	3.55	3.73	29.9	1.05	1.02	4.3
		08/01/76	1530		27.20	21.35	6.43	33.11	0.11	77.0	3.23	34.59	19.4	1.17	1.01	14.2
		08/01/76	2330		26.10	20.80	9.80	35.80	0.28	8.1	3.34	3.40	27.4	1.04	1.01	2.6
		08/02/76	0730		25.91	18.33	10.72	33.63	0.19	7.9	2.58	3.54	31.9	1.10	1.01	4.1
		08/02/76	1530		25.81	18.74	12.07	35.49	0.44	7.8		3.35	34.0	1.04	1.02	1.5
		08/02/76	2330		25.45	19.38	11.60	35.45	0.31	7.9		3.41	32.7	1.04	1.02	2.4
		08/03/76	0730		25.15	18.89	13.63	37.23	0.27	7.5	2.87	3.16	36.6	0.96	1.01	-5.1
		08/03/76	1530		26.71	20.92	9.10	35.25	0.11	7.8		3.37	25.8	1.08	1.01	7.0
		08/03/76	2330		23.50	16.83	11.30	32.33	0.49	8.1		3.88	34.9	1.04	1.03	1.0
		08/04/76	0530		24.08	18.06	11.11	33.68	0.37	7.3		3.39	33.0	1.02	1.02	0.1
	2821	07/29/76	1537		21.50	14.80	14.20	32.70	0.36	63.0		30.96	43.4	0.94	1.02	-8.7
		07/30/76	1530		23.40	19.70	8.78	33.40	0.27	60.0		23.71	26.3	1.00	1.01	-1.5
		08/02/76	1530		23.77	17.37	10.30	32.01	0.66	58.0		27.79	32.2	1.06	1.04	2.1
		08/03/76	1530		24.03	18.82	9.93	33.45	0.19	60.0		28.22	29.7	1.03	1.01	1.5
605-2A	2816	08/05/76	0330		27.42	23.16	6.69	35.64	0.77	7.1		2.98	18.8	1.10	1.04	5.4
		08/06/76	0730		30.80	25.73	9.68	41.84	0.69	7.0	1.86	2.32	23.1	1.05	1.03	2.9
		08/06/76	1530		25.55	23.67	5.30	34.88	0.58	8.2		3.68	15.2	1.05	1.03	1.5
		08/06/76	2330		23.25	19.72	9.43	34.08	0.66	7.9		3.71	27.7	0.97	1.04	-6.2
		08/07/76	0730		26.48	23.53	4.97	34.28	0.68	7.9	2.61	3.51	14.2	1.10	1.04	6.0
		08/07/76	1530		25.00	21.75	5.11	32.29	0.45	8.4		4.01	15.8	1.11	1.03	7.2
		08/07/76	2330		26.74	23.86	6.17	35.99	0.71	8.1		3.44	17.1	1.06	1.04	2.3
		08/08/76	0730		27.07	23.71	6.64	36.27	0.58	8.1	2.89	3.40	18.3	1.07	1.03	3.4
		08/08/76	1530		28.63	24.84	9.13	40.18	0.63	8.1		2.98	22.7	1.02	1.03	-1.1
		08/08/76	2330		29.67	23.34	9.98	39.15	0.93	8.4		3.03	25.5	1.09	1.04	3.6
		08/09/76	0730		26.70	24.14	9.76	39.93	0.58	7.7	2.73	2.99	24.4	0.95	1.03	-7.5
		08/09/76	1530		28.23	25.22	8.56	40.48	0.26	7.5		2.91	22.1	1.00	1.01	-1.6
		08/09/76	2330		29.92	26.42	7.50	40.92	0.44	7.5		2.65	19.3	1.04	1.02	2.3
		08/10/76	0730		28.02	24.25	6.66	36.97	0.77	7.7	2.08	3.10	18.0	1.08	1.04	4.1
		08/10/76	1530		24.02	21.40	9.54	36.29	0.36	8.0		3.57	26.3	0.94	1.02	-7.7
		08/10/76	2330		26.42	24.40	4.64	35.14	0.31	7.8		3.45	13.2	1.07	1.02	5.3
		08/11/76	0730		27.69	24.61	7.49	38.25	0.55	8.8	1.37	3.49	19.6	1.03	1.03	0.7
		08/11/76	1530		27.25	25.19	6.66	38.14	0.47	7.9		3.13	17.5	1.02	1.02	-0.2
		08/11/76	2330		29.38	27.83	5.50	39.28	0.27	7.6		2.87	14.0	1.07	1.01	5.2
		08/12/76	0730		29.75	28.23	6.65	41.93	0.46	7.3	1.32	2.55	15.9	1.01	1.02	-0.7
		08/12/76	1930		29.43	25.46	11.62	43.44	0.19	7.2		2.40	26.7	0.97	1.01	-4.2
		08/12/76	2330		29.40	26.37	5.14	38.85	0.62	7.7		2.92	13.2	1.08	1.03	4.8
		08/13/76	0730		28.12	26.71	5.78	39.16	0.82	7.4	1.83	2.85	14.8	1.03	1.04	-1.3
	2821	08/06/76	1530		26.15	23.75	4.88	34.56	0.69	49.0		21.32	14.1	1.08	1.04	4.1
		08/07/76	1530		24.65	21.64	4.30	31.35	0.48	57.0		27.89	13.7	1.12	1.03	8.4

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
605-2A	2821	08/08/76	1530		24.67	21.97	5.09	32.55	0.62	55.0		25.21	15.6	1.08	1.03	4.4
		08/09/76	1530		26.20	23.38	7.54	36.76	0.21	55.0		23.47	20.5	1.02	1.01	0.7
		08/10/76	1530		23.49	21.72	7.32	34.97	0.21	56.0		26.10	22.4	0.96	1.01	-5.4
		08/11/76	1530		25.31	23.75	4.63	34.29	0.21	52.0		23.97	13.4	1.05	1.01	4.1
606-2A	2816	08/13/76	1530		25.64	24.25	3.73	34.04	0.88	8.1		3.69	11.0	1.09	1.05	2.6
		08/13/76	2330		31.57	20.14	17.35	42.52	1.21	8.0		2.38	40.8	1.06	1.05	0.8
		08/14/76	0730		24.87	20.99	9.22	35.45	0.44	7.5	2.32	3.38	25.0	1.00	1.02	-2.1
		08/14/76	1530		23.47	19.90	8.18	33.05	0.49	8.0		3.54	24.7	1.01	1.03	-1.3
		08/14/76	2330		23.40	19.06	9.15	32.97	0.43	8.0		3.84	27.7	1.01	1.02	-1.0
		08/15/76	0730		21.86	16.75	10.86	31.79	0.82	7.7	3.42	3.93	34.1	0.98	1.05	-3.6
		08/15/76	1530		20.83	17.55	8.96	30.89	0.33	8.2		4.29	29.0	0.96	1.02	-4.9
		08/15/76	2330		24.55	21.81	6.40	33.66	2.27	8.1		3.64	19.0	1.04	1.12	-7.8
		08/16/76	0730		27.52	20.30	12.60	37.97	0.71	7.4	2.23	2.98	33.2	1.03	1.03	0.1
		08/16/76	1530		25.93	25.33	3.20	34.86	1.40	9.3		4.11	9.2	1.06	1.07	-1.1
		08/16/76	2330		24.90	24.34	3.67	34.09	1.04	7.8		3.59	10.8	1.04	1.06	-1.2
		08/17/76	0730		22.88	20.30	6.83	32.20	1.02	7.6		3.72	21.2	1.01	1.06	-4.3
		08/17/76	1530		21.70	18.45	6.90	29.96	1.32	8.2		4.23	23.0	1.03	1.09	-4.5
		08/17/76	2330		23.11	17.51	6.92	28.80	0.93	7.4		3.91	24.0	1.15	1.06	7.2
		08/18/76	0730		20.33	18.36	3.94	26.89	0.43	8.0		4.56	14.7	1.08	1.03	4.7
		08/18/76	1345		23.15	22.44	6.50	34.55	0.71	8.6		4.06	18.8	0.96	1.04	-2.4
	2821	08/13/76	1530		24.90	26.42	0.44	33.46	0.66	53.9		25.65	1.3	1.06	1.04	2.5
		08/14/76	1530		22.51	19.54	6.26	30.68	0.55	59.2		30.28	20.4	1.05	1.03	1.4
		08/15/76	1530		21.01	15.56	11.15	30.60	0.82	59.9		30.82	36.4	0.98	1.05	-7.0
		08/16/76	1530		24.26	22.44	2.88	30.93	1.15	58.7	3.02	28.92	9.3	1.12	1.07	4.7
		08/17/76	1530		21.76	19.18	6.66	30.63	1.15	59.5	3.05	30.50	21.7	1.01	1.07	-5.3
		08/18/76	1345		20.72	19.54	6.17	30.59	0.82	60.0		31.65	20.2	0.97	1.05	-5.5
607-2A	2816	08/19/76	1600		21.95	20.63	6.32	32.10	0.66	6.9		3.43	19.7	0.98	1.04	-6.3
		08/19/76	2330		25.39	24.83	2.05	33.08	0.38	8.5		4.03	6.2	1.10	1.02	5.8
		08/20/76	0730		22.26	23.14	0.35	29.27	0.31	7.9	3.07	4.26	1.2	1.09	1.02	5.1
		08/20/76	1530		24.58	25.52	0.04	31.93	0.13	7.5		3.73	0.1	1.10	1.01	8.3
		08/20/76	2330		25.44	26.06	2.45	35.03	0.82	8.0		3.62	7.0	1.04	1.04	-0.6
		08/21/76	0730		25.63	25.03	2.04	33.32	0.56	7.4	2.39	3.46	6.1	1.10	1.03	6.2
		08/21/76	1530		25.47	25.40	1.53	33.27	0.76	9.0		3.75	4.6	1.09	1.04	4.7
		08/21/76	2330		28.46	24.32	7.78	38.18	0.69	8.2		3.15	20.4	1.09	1.03	4.3
		08/22/76	0730		25.89	23.32	3.53	32.68	0.72	7.7	2.35	3.59	10.9	1.13	1.04	8.0
		08/22/76	1530		25.59	25.97	1.39	33.85	0.63	7.8	3.80	3.62	4.1	1.08	1.03	4.2
		08/22/76	2330		25.34	21.89	4.21	31.57	0.88	7.6		3.62	13.3	1.15	1.05	8.3
		08/23/76	0730		23.50	18.09	7.43	30.03	0.65	7.5	2.89	3.77	24.5	1.12	1.04	7.4
		08/23/76	1530		27.89	21.19	8.24	34.72	0.96	7.7		3.21	23.7	1.15	1.05	9.4
		08/23/76	2330		23.21	19.61	6.17	30.68	0.60	7.7		3.83	20.1	1.08	1.04	4.1
					23.25	19.61	11.07	35.58	0.60				31.1	0.93	1.03	-10.5
		08/24/76	0730		26.15	21.71	6.34	33.47	0.38	7.0	2.14	3.18	18.9	1.12	1.02	8.5
					26.79	21.71	6.34	33.47	0.38				18.9	1.14	1.02	10.7

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
507-2A	2816	08/24/76	1530		25.28	23.71	3.12	32.75	1.01	7.6		3.56	9.5	1.10	1.06	4.2
		08/24/76	2330		25.18	21.06	6.82	33.14	0.75	7.1		3.28	20.6	1.08	1.04	4.0
		08/25/76	0530		22.48	19.18	6.43	30.40	1.16	7.1	2.55	3.60	21.1	1.06	1.07	-1.3
		08/30/76	1530		24.26	20.74	.33	32.25	1.24	7.6		3.61	19.6	1.07	1.07	0.4
		08/30/76	2330		25.19	24.28	2.51	32.86	0.84	7.5		3.54	7.7	1.09	1.05	4.4
		08/31/76	0730		24.26	20.04	6.60	32.65	1.00	8.2		3.49	20.2	1.06	1.06	0.5
					24.26	20.04	6.60	32.65	1.06	8.2	2.57	3.37	20.2	1.06	1.06	0.2
		08/31/76	1530		28.47	25.15	7.71	39.15	1.46	7.5	3.83	2.79	19.7	1.04	1.07	-2.0
					24.63	24.28	0.61	30.96	1.46				2.0	1.14	1.09	4.4
		08/31/76	2330		25.91	22.44	3.95	32.80	1.13	7.9		3.68	12.4	1.16	1.06	7.9
		09/01/76	0730		25.73	23.79	13.84	43.57	0.94	8.6	2.09	2.73	31.8	0.97	1.04	-6.7
		09/01/76	1530		26.38	20.99	10.72	36.95	1.27	8.2		3.33	29.0	1.02	1.06	-4.2
		09/01/76	2330		26.82	23.83	6.26	36.11	1.04	8.6		3.61	17.3	1.06	1.05	0.7
		09/02/76	0730		25.52	21.25	9.13	35.69	1.13	8.2	2.06	3.52	25.6	1.02	1.06	-3.6
					35.73	21.25	14.38	40.54	1.13				35.1	1.25	1.05	15.7
		09/02/76	1530		28.75	26.24	6.44	39.23	1.55	8.5		3.14	16.4	1.05	1.07	-2.5
	2821	08/19/76	1600		25.26	20.63	7.12	32.90	0.66	58.0	33.35	29.04	21.6	1.01	1.04	-2.7
					21.99	20.63	7.99	33.77	0.60	58.0	33.35	28.30	23.7	0.93	1.03	-11.0
					23.26	20.63	7.12	32.90	0.66				21.6	1.01	1.04	-2.7
		08/20/76	1530		22.40	22.82	0.51	25.03	0.20	62.0		33.53	1.8	1.10	1.01	6.1
		08/21/76	1530		25.30	24.53	1.88	32.54	0.92	57.0		27.00	5.8	1.11	1.05	5.3
		08/22/76	1530		22.98	24.04	0.77	30.82	0.76	54.0		27.78	2.5	1.06	1.04	1.8
		08/23/76	1530		25.90	21.22	7.38	33.99	0.86	52.0		23.23	21.7	1.08	1.05	3.5
		08/24/76	1530		25.30	23.60	2.95	32.70	1.18	55.0		25.72	9.0	1.10	1.07	3.5
		08/30/76	1530		23.71	19.21	8.45	32.46	1.25	54.0		25.59	26.0	1.04	1.07	-2.6
	2825	08/31/76	1530													
		09/01/76	1530													
		09/02/76	1530													
508-2A	2816	09/03/76	1530		27.61	26.53	5.64	38.80	1.55	14.8		5.72	14.5	1.02	1.07	-5.6
		09/03/76	2330		29.38	25.51	8.05	39.93	0.82	14.5		5.26	20.2	1.05	1.04	1.2
		09/04/76	0730		26.97	24.61	6.53	37.29	1.15	14.5	4.33	5.91	17.5	1.03	1.06	-2.3
		09/04/76	1530		28.69	24.81	10.01	41.02	1.01	15.7		5.57	24.4	1.00	1.04	-4.6
		09/04/76	2330		27.21	22.07	9.79	37.37	0.94	14.5		5.30	26.2	1.04	1.05	-0.6
		09/05/76	0730		27.00	24.86	5.82	36.89	1.43	15.4	4.53	6.30	15.8	1.04	1.07	-2.5
		09/05/76	1530		28.54	26.15	6.45	39.13	0.94	14.9		5.65	16.5	1.04	1.04	-0.2
		09/05/76	2330		27.95	23.34	8.19	37.36	1.04	13.4		5.29	21.9	1.07	1.05	1.6
		09/06/76	0730		27.35	23.15	7.55	36.50	1.12	15.0	4.59	6.12	20.7	1.07	1.06	1.3
		09/06/76	1530		25.24	20.81	7.34	33.35	1.36	14.1		6.38	22.0	1.06	1.07	0.6
		09/07/76	0730		29.86	28.64	5.23	41.27	1.50	15.2	3.99	5.26	12.7	1.03	1.07	-3.2
	2825	09/03/76	1530													
		09/04/76	1530													
		09/05/76	1530													
		09/06/76	1530													
508-2B	2816	09/07/76	0330		29.64	24.97	9.39	40.60	1.27	15.5		5.38	23.1	1.04	1.06	-1.4

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
608-2A	2816	09/07/76	0730		26.09	25.69	2.22	34.33	1.40	15.3	4.40	6.82	6.5	1.08	1.07	1.0
		09/07/76	1130													
		09/07/76	1530		29.70	27.93	3.27	38.18	1.07	15.3		5.97	8.6	1.07	1.05	0.1
		09/07/76	1930													
		09/07/76	2330		30.14	28.67	5.65	41.48	1.12	15.6		5.37	13.6	1.04	1.05	-1.1
		09/08/76	1530		28.27	25.31	5.27	36.90	1.02	15.1		6.06	14.3	1.09	1.05	4.0
		09/08/76	2330		23.54	27.09	4.55	38.41	1.58	14.7		5.62	11.9	1.06	1.07	-1.5
		09/09/76	0730		27.42	25.69	5.33	37.50	1.43	14.6	4.55	5.61	14.6	1.04	1.07	-2.8
		09/09/76	1600		27.75	24.51	7.01	37.64	1.22	15.1		5.97	19.6	1.05	1.06	-0.9
		09/09/76	2330		25.86	24.20	2.41	32.66	1.54	14.5		5.71	7.4	1.17	1.09	4.2
		09/10/76	0730		25.73	21.17	7.93	34.39	1.76	14.3	5.08	6.21	23.1	1.07	1.09	-0.3
		09/10/76	1530		27.62	24.61	4.43	35.19	1.59	15.1		6.27	12.6	1.13	1.09	4.1
		09/10/76	2330		28.03	25.08	4.31	36.15	1.66	14.2		5.74	13.3	1.11	1.08	2.1
		09/11/76	0730		26.13	26.31	2.65	35.53	1.84	14.5	4.81	6.25	7.5	1.05	1.09	-6.5
		09/11/76	1530		27.75	26.79	5.27	38.74	1.42	14.9		5.75	13.5	1.02	1.07	-6.9
		09/11/76	2330		27.42	27.15	2.61	36.54	1.52	14.8		6.11	7.1	1.07	1.08	-0.4
		09/12/76	0730		27.94	28.41	2.51	38.02	1.63	14.8	4.19	5.95	6.6	1.05	1.08	-2.9
		09/12/76	1530		29.20	28.59	4.50	40.23	1.42	14.4		5.23	11.2	1.04	1.06	-2.7
		09/12/76	2330	X	38.58	29.07	11.85	48.22	1.67	15.4		2.89	24.7	1.14	1.05	6.9
		09/13/76	0600		27.58	27.87	-0.04	34.79	0.65		4.19		-0.1	1.13	1.03	6.6
	2825	09/08/76	1530													
		09/09/76	1600													
		09/10/76	1530													
		09/11/76	1530													
		09/12/76	1530													
609-2A	2816	09/13/76	1530		25.20	26.42	1.59	34.61	0.25	7.3		3.32	4.6	1.08	1.01	6.3
		09/13/76	2330		30.63	28.06	8.03	43.10	0.48	9.3		2.72	18.6	1.01	1.02	-0.6
		09/14/76	0730		29.09	28.76	1.31	37.25	0.31	8.7	2.24	3.61	3.5	1.08	1.02	5.7
		09/14/76	1530		25.92	26.78	0.37	33.84	0.20	7.8		3.65	1.1	1.09	1.01	7.6
						26.60	0.17	33.41					0.5			
		09/14/76	2330		26.20	26.60	3.53	36.77	0.94	8.0		3.42	9.6	1.02	1.05	-2.9
		09/15/76	0730		24.09	22.57	2.08	30.29	0.75	8.2	3.14	4.14	6.9	1.14	1.05	6.0
		09/15/76	1345													
		09/15/76	1600		24.10	22.09	2.95	30.46	0.66	7.7		3.87	9.4	1.13	1.04	8.0
		09/15/76	2330		21.90	19.90	3.70	28.57	0.25	8.0		4.34	12.9	1.09	1.02	7.2
		09/16/76	0730		20.66	20.45	1.36	26.92	0.17	8.1	2.92	4.65	5.1	1.10	1.01	7.7
		09/16/76	1530		23.33	23.34	0.88	30.05	0.60	7.7		3.99	2.9	1.11	1.04	6.5
		09/16/76	2330		23.76	22.67	6.54	34.87	0.29	8.0		3.74	13.7	0.97	1.02	-4.4
					28.83	22.07	2.02	29.60	0.29	8.0		3.74	6.8	1.39	1.02	26.8
		09/17/76	0730		26.17	24.79	4.55	35.54	0.50	7.4	2.40	3.26	12.8	1.05	1.03	2.4
		09/17/76	1530		26.56	25.43	3.83	35.96	0.38	7.8		3.40	10.7	1.06	1.02	3.6
		09/17/76	2330		26.23	24.79	6.68	37.66	0.50	7.1		2.97	17.7	0.99	1.02	-3.0
		09/18/76	0730		25.11	23.79	7.15	36.88	0.66	8.5	2.84	3.55	19.4	0.97	1.03	-5.7
		09/18/76	1530		26.14	23.77	5.47	35.18	0.56	8.2		3.61	15.6	1.06	1.03	7.0
		09/18/76	2330		24.33	23.34	4.05	33.22	0.13	7.6		3.60	12.2	1.05	1.01	4.7

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
609-2A	2816	09/19/76	0730		24.77	22.84	4.35	32.90	0.41	8.5	2.91	4.05	13.2	1.07	1.02	4.9
		09/19/76	1530		24.17	22.62	4.39	33.16	0.60	8.1		3.87	14.7	1.04	1.03	0.7
		09/19/76	2330		26.31	26.53	3.11	36.27	0.50	7.9		3.44	3.6	1.04	1.03	1.0
		09/20/76	0730		22.71	21.35	3.85	30.53	0.67	8.1	3.23	4.17	12.6	1.06	1.04	2.1
		09/20/76	1530		22.07	19.62	5.84	30.36	0.61	7.6		3.94	19.2	1.04	1.04	0.1
		09/20/76	2330		20.74	18.27	6.99	29.82	0.44	8.6		4.61	23.4	0.99	1.03	-7.4
		09/21/76	0730		25.69	22.07	6.78	34.36	0.32	7.5	2.67	3.37	19.7	1.07	1.03	3.7
		09/21/76	1530		23.40	20.43	8.99	34.52	0.52	8.1		3.78	26.0	0.97	1.03	-6.2
		09/21/76	2330		23.51	19.84	8.52	33.32	0.55	7.9		3.76	25.6	1.01	1.03	-2.3
		09/22/76	0730		26.79	24.81	6.60	37.61	0.41	8.0	3.02	3.30	18.0	1.01	1.02	-0.8
		09/22/76	1530		24.35	25.87	3.81	36.14	0.35	8.6		3.92	10.5	0.96	1.02	-5.8
		09/22/76	2330		22.46	22.02	5.34	32.86	0.42	8.3		4.13	16.2	0.98	1.02	-4.9
		09/23/76	0730		25.05	22.07	9.06	36.64	0.40	7.6	3.21	3.30	24.7	0.96	1.02	-4.5
		09/23/76	1530		25.73	22.62	7.81	36.08	0.62	8.4		3.63	21.6	1.02	1.03	-1.3
		09/23/76	2330		22.20	20.74	6.14	32.06	0.37	8.7		4.40	19.1	0.99	1.02	-3.3
		09/24/76	0500		19.49	19.18	3.28	27.25	0.26	8.5	3.83	4.91	12.0	1.02	1.02	0.4
	2825	09/13/76	1530													
		09/14/76	1530													
		09/15/76	1600													
		09/16/76	1530													
		09/17/76	1530													
		09/18/76	1530													
		09/19/76	1530													
		09/20/76	1530													
		09/21/76	1530													
		09/22/76	1530													
		09/23/76	1530													
610-2A	2816	09/24/76	1530		20.42	19.54	3.14	27.56	0.43	8.4		4.74	11.4	1.06	1.03	2.8
		09/24/76	2330		24.23	24.79	0.85	31.83	0.70	8.0		3.96	2.7	1.09	1.04	4.3
		09/25/76	0730		24.60	24.61	4.10	34.86	0.62	8.1	2.52	3.73	11.8	1.01	1.03	-2.5
		09/25/76	1530		25.38	24.61	4.52	35.28	0.50	8.4		3.78	12.8	1.03	1.03	0.1
		09/25/76	2330		23.77	24.57	0.98	31.69	0.66	7.7		3.85	3.1	1.07	1.04	3.1
		09/26/76	0730		23.73	22.62	2.00	30.27	0.46	7.9	2.91	4.04	6.6	1.12	1.03	8.2
		09/26/76	1530		24.57	25.15	1.16	32.59	0.49	8.1		3.94	3.6	1.08	1.03	4.5
		09/26/76	2330		28.55	28.95	3.00	39.18	0.57	7.6		2.96	7.7	1.04	1.03	1.3
		09/27/76	0730		23.38	24.25	0.67	30.98	0.75	8.0	2.67	4.13	2.9	1.06	1.02	4.0
		09/27/76	1530		23.17	24.07	3.57	33.65	0.54	7.9		3.69	10.6	1.07	1.03	3.6
		09/27/76	2330		25.74	24.97	2.83	34.04	0.59	8.5		3.61	8.3	1.08	1.03	4.4
		09/28/76	0730		26.79	27.03	1.49	35.27	0.76	7.8	2.12	3.43	4.2	1.08	1.04	4.2
		09/28/76	1530		24.60	25.33	0.81	32.47	0.99	7.8		3.77	2.5	1.08	1.06	2.4
		09/28/76	2330		24.27	24.61	1.20	31.96	0.66	8.0		3.94	3.8	1.08	1.04	4.3
		09/30/76	0730		24.53	23.51	2.49	31.87	0.98	7.6	2.52	3.69	7.8	1.10	1.06	3.9
		09/30/76	1530		24.63	22.44	4.19	32.23	0.60	8.2		3.93	13.0	1.09	1.05	4.2
		09/30/76	2330		25.43	24.97	3.20	34.41	0.67	7.8		3.57	9.3	1.05	1.04	1.9
		10/01/76	0730		25.60	25.01	4.79	36.05	1.06	8.5	2.83	3.61	13.3	1.01	1.05	-5.9

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
610-2A	2816	10/01/76	1530		25.13	24.61	3.78	34.54	1.03	7.8		3.55	11.0	1.04	1.05	-1.5
		10/01/76	2330		23.34	21.35	3.08	29.76	0.90	8.7		4.47	10.3	1.12	1.06	5.8
		10/02/76	0730		25.00	22.62	3.68	31.95	1.04	6.3	2.95	3.96	11.5	1.12	1.05	5.2
		10/02/76	1530		23.42	22.30	2.33	30.20	1.08	8.0		4.07	7.7	1.11	1.07	3.8
		10/02/76	2330		22.42	21.57	1.58	28.54	0.79	8.1		4.35	5.5	1.12	1.05	4.3
		10/03/76	0730		21.97	19.54	4.03	28.45	0.71	7.6	2.92	4.09	14.2	1.10	1.05	5.2
		10/03/76	1530		19.99	17.96	2.97	25.42	0.65	7.4		4.31	11.7	1.12	1.06	5.5
		10/03/76	2330		22.26	18.09	5.51	28.12	0.93	7.7		4.10	19.6	1.13	1.06	6.2
		10/04/76	0500		24.42	22.15	3.84	31.52	0.74	7.9	2.91	3.86	12.2	1.11	1.04	5.7
		10/04/76	1530		24.31	22.05	3.08	30.64	0.91	7.2		3.57	10.1	1.13	1.05	6.9
		10/04/76	2330		22.97	22.07	3.77	31.35	0.66	7.9		3.99	12.0	1.05	1.04	0.7
		10/05/76	0730		22.51	20.75	3.84	29.77	0.51	7.4	2.39	3.88	12.9	1.08	1.03	4.5
		10/05/76	1530		19.19	18.81	2.49	26.00	0.76	7.6		4.47	9.6	1.05	1.05	0.0
		10/05/76	2330		20.56	19.78	1.66	26.38	0.89	7.6		4.34	6.3	1.11	1.06	4.6
		10/06/76	0730		22.48	22.44	0.87	28.92	0.47	7.6	1.84	4.08	3.0	1.11	1.03	7.2
		10/06/76	1530		22.93	21.11	2.51	28.89	0.91	8.1		4.26	8.7	1.13	1.06	6.7
		10/06/76	2330		21.12	21.35	0.25	26.93	0.68	7.3		4.13	0.9	1.12	1.05	6.6
		10/07/76	0730		21.50	20.81	0.83	26.84	1.02	6.0	2.36	4.47	3.1	1.14	1.07	6.5
	2821	09/27/76	1530		25.51	24.54	2.89	33.56	0.50	52.2	1.03	24.31	8.6	1.09	1.03	5.4
		09/29/76	1530		26.29	26.49	2.68	35.79	0.99	53.1	9.40	23.13	7.5	1.05	1.05	-0.2
	2825	09/24/76	1530													
		09/25/76	1530													
		09/26/76	2330													
		09/27/76	1530													
		09/29/76	1530													
		09/30/76	1530													
		10/01/76	1530													
		10/02/76	1530													
		10/03/76	1530													
		10/04/76	1530													
		10/05/76	1014													
		10/06/76	1530													
611-2A	2816	10/07/76	1530		20.44	20.18	3.64	25.86	0.98	7.3		4.22	2.5	1.13	1.07	5.3
		10/07/76	2330		22.75	18.32	6.31	29.21	0.80	7.3		3.78	21.6	1.11	1.05	5.6
		10/08/76	0730		21.64	17.91	6.01	28.39	0.55	8.7	2.36	4.69	21.2	1.09	1.04	4.9
		10/08/76	1530		20.56	14.29	7.60	25.46	0.77	8.0		4.54	29.9	1.15	1.06	8.5
		10/08/76	2330		21.75	16.67	7.47	28.30	0.99	6.9		3.67	26.4	1.10	1.06	3.1
		10/09/76	0730		24.33	16.64	10.93	31.73	0.71	8.3	2.90	3.93	34.5	1.09	1.04	4.9
		10/09/76	1530		27.70	19.18	13.27	37.24	0.60	6.3		3.26	35.6	1.06	1.03	3.1
		10/09/76	2330		23.04	16.09	6.63	29.24	1.54	8.3		4.21	22.7	1.12	1.10	2.6
		10/10/76	0730		24.95	16.64	12.20	33.00	0.60	8.1	2.33	3.69	37.0	1.08	1.03	4.3
		10/10/76	1530		22.21	16.10	8.79	28.91	0.66	8.4		4.39	30.4	1.10	1.04	5.0
		10/10/76	2330		24.75	21.89	5.17	32.53	0.68	7.8		3.69	15.9	1.09	1.05	3.4
		10/11/76	0730		25.46	17.55	12.88	34.61	0.16	7.5	2.51	3.30	37.0	1.04	1.01	3.4
		10/11/76	1530		21.95	17.41	7.68	29.44	0.61	8.4		4.40	26.1	1.06	1.04	2.5

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
611-2A	2816	10/11/76	2330		25.86	14.07	20.73	36.31	0.16	7.5		2.94	54.1	0.96	1.01	-4.6
					25.86	13.46	19.81	36.63	0.16				54.1	1.01	1.01	0.0
		10/12/76	0530		23.93	18.64	9.73	32.03	0.77	8.9	3.03	4.27	27.3	1.07	1.04	2.1
	2825	10/07/76	1530													
		10/08/76	1530													
		10/09/76	1530													
		10/10/76	1530													
		10/11/76	1530													
612-2A	2816	10/12/76	1530		24.83	16.83	11.74	32.77	0.11	8.2		3.81	35.8	1.08	1.01	7.0
		10/12/76	2330		24.50	18.64	9.59	32.89	0.11	7.4		3.49	29.2	1.06	1.01	5.4
		10/13/76	0730		23.63	17.21	9.25	30.76	0.27	9.2	3.31	4.57	30.1	1.10	1.02	7.4
		10/13/76	1530		25.85	19.00	9.83	33.58	0.33	8.1		3.64	29.3	1.10	1.02	7.4
		10/13/76	2330		25.42	16.99	11.85	33.08	0.16	8.6		3.92	35.8	1.10	1.01	8.0
		10/14/76	0730		24.37	15.53	11.83	31.24	0.35	8.0	2.71	3.83	37.9	1.11	1.02	8.4
		10/14/76	1530		24.76	19.18	8.11	32.08	0.66	7.0		3.31	25.3	1.10	1.04	5.8
		10/14/76	2330		25.23	20.26	9.72	35.04	0.33	8.0		3.48	27.7	1.07	1.02	4.8
		10/15/76	0730		24.59	16.95	11.80	32.98	0.53	8.1	2.70	3.74	35.8	1.06	1.03	3.3
		10/15/76	1530		26.15	18.09	12.33	34.94	0.16	7.1		3.07	35.3	1.07	1.01	5.6
		10/15/76	2330		21.00	17.01	7.02	28.34	0.49	8.4		4.57	25.0	1.06	1.03	2.5
		10/16/76	0730		27.10	19.79	11.22	35.95	0.23	7.9	2.32	3.29	31.2	1.08	1.01	6.0
		10/16/76	1530		25.99	19.48	10.65	35.00	0.32	7.4		3.23	30.4	1.06	1.02	3.7
		10/16/76	2330		23.97	18.33	9.06	31.97	0.49	8.5		4.09	28.3	1.07	1.03	4.0
		10/17/76	0730		23.92	18.62	8.83	32.10	0.34	8.2	2.91	3.96	27.5	1.06	1.02	4.2
		10/17/76	1530		21.76	17.05	8.34	29.65	0.16	7.6		4.00	28.1	1.05	1.01	3.6
		10/17/76	2330		24.00	17.73	9.64	31.80	0.44	7.6		3.66	30.3	1.08	1.03	4.9
		10/18/76	0730		23.72	18.09	8.96	31.57	0.42	8.0	2.54	3.91	28.4	1.07	1.02	4.5
	2825	10/12/76	1530													
		10/13/76	1530													
		10/14/76	1530													
		10/15/76	1530													
		10/16/76	1530													
		10/17/76	1530													
613-2A	2816	10/18/76	1930		27.91	25.35	5.40	37.08	0.44	8.4		3.44	14.6	1.07	1.02	4.9
		10/19/76	2330		19.72	19.54	1.71	26.13	0.27	7.9		4.64	6.5	1.08	1.02	5.4
		10/19/76	0730		28.22	20.63	13.45	39.23	0.71	7.6	2.23	2.81	34.3	1.03	1.03	-0.6
		10/19/76	1530		28.36	17.73	17.23	39.39	0.16	8.4		3.07	43.7	1.03	1.01	2.0
		10/19/76	2330		22.42	14.31	12.91	30.79	0.46	8.3		4.14	41.9	1.04	1.03	1.2
		10/20/76	0730		23.13	15.56	11.24	30.69	0.77	8.7	1.87	4.29	36.6	1.08	1.05	2.8
		10/20/76	1530		21.48	15.99	7.59	27.57	0.35	6.9		3.77	27.5	1.11	1.02	8.0
		10/20/76	2330		22.95	15.36	10.02	29.22	0.78	8.1		4.12	34.3	1.12	1.05	6.5
		10/21/76	0730		23.91	17.01	11.57	32.83	0.33	8.4	3.20	3.97	35.2	1.04	1.02	1.7
	2825	10/18/76	1930													
		10/19/76	1530													
		10/20/76	1530													
614-2A	2816	10/21/76	1530		21.98	20.99	0.84	27.07	1.15	4.0		2.20	3.1	1.16	1.08	7.1

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
614-2A	2816	10/22/76	2330		26.40	24.54	2.90	33.57	1.00	9.1		4.11	6.6	1.12	1.05	6.1
		10/23/76	0730		22.62	20.63	2.47	28.25	0.33	8.1	3.05	4.37	8.7	1.14	1.02	10.7
					22.60	20.63	1.87	27.65	0.49				6.8	1.17	1.03	11.5
		10/23/76	1530		25.63	21.53	5.98	32.89	0.50	8.6		3.98	18.2	1.11	1.03	7.1
		10/23/76	2330		23.73	20.64	4.45	30.25	0.73	8.2		4.14	14.7	1.12	1.04	6.6
		10/24/76	0730		23.40	19.36	5.10	29.30	1.15	8.0	2.44	4.00	17.4	1.14	1.07	6.0
		10/24/76	1530		22.41	19.00	5.23	28.98	0.82	7.6		4.10	15.1	1.10	1.05	4.9
		10/24/76	2330		23.93	21.40	3.49	30.24	0.75	8.1		4.08	11.5	1.13	1.05	7.5
		10/25/76	0930		22.55	19.54	3.95	28.37	0.63	7.8	2.42	4.15	13.9	1.13	1.04	6.5
		10/25/76	1530		23.67	21.35	3.29	29.97	0.66	8.0		4.08	11.0	1.13	1.04	7.8
		10/25/76	2330		23.73	23.77	0.80	30.51	0.80	9.0		4.07	2.6	1.11	1.05	5.6
		10/26/76	0730		24.51	22.75	2.28	30.71	0.77	7.6	2.64	3.82	7.5	1.14	1.05	5.2
		10/26/76	1530		25.97	21.70	5.98	33.10	0.99	7.9		3.58	18.1	1.12	1.05	5.9
		10/26/76	2330		26.99	25.31	3.26	34.91	2.00	8.3		3.52	9.4	1.12	1.10	6.3
		10/27/76	0730		27.60	25.41	2.89	34.65	0.83	7.8		3.37	8.3	1.14	1.04	8.7
		10/27/76	1530		25.72	24.23	5.49	35.77	0.22	9.0		3.55	15.3	1.03	1.01	1.5
		10/27/76	2330		23.43	22.78	1.01	29.48	0.63	8.5		4.43	3.4	1.13	1.04	8.4
		10/28/76	0730		22.55	20.79	3.56	29.54	0.39	9.1	3.55	4.60	12.0	1.09	1.02	6.0
615-2A	2816	10/28/76	1530		20.82	22.42	1.57	29.59	0.55	9.8		4.61	5.3	1.00	1.03	-2.9
		10/28/76	2330		23.82	24.22	3.31	33.58	1.65	7.7		3.62	9.5	1.01	1.00	-7.6
		10/29/76	0730		24.29	21.42	6.59	33.36	0.41	7.5	2.48	3.55	17.6	1.04	1.02	1.6
		10/29/76	1530		25.29	22.55	5.12	33.30	0.52	9.4		3.91	15.4	1.09	1.03	5.1
		10/29/76	2330		23.04	18.45	7.36	30.42	0.71	8.1		4.09	24.2	1.05	1.04	3.6
		10/30/76	0730		20.11	16.28	6.32	26.67	0.60	8.6	3.42	4.89	23.7	1.09	1.04	7.3
		10/30/76	1530		20.36	17.65	4.47	26.53	0.65	7.9		4.49	16.9	1.10	1.04	4.7
		10/30/76	2330		19.90	16.64	6.26	27.06	0.33	7.7		4.38	23.1	1.05	1.02	2.6
		11/01/76	1530		18.54	15.56	4.43	23.88	0.77	7.6		4.61	18.6	1.11	1.06	4.5
		11/01/76	2330		19.81	18.45	2.16	25.22	0.82	8.3		4.86	8.6	1.12	1.06	5.5
		11/02/76	0730		22.47	19.18	5.74	29.71	0.16	7.8	3.27	4.09	19.3	1.08	1.01	6.5
		11/02/76	1530		22.57	21.04	4.02	30.32	0.19	9.4		4.34	13.3	1.06	1.01	4.6
		11/02/76	2330		22.71	18.45	8.78	31.84	0.16	8.6		4.29	27.6	1.02	1.01	0.9
		11/03/76	0730		23.82	20.48	6.95	32.55	0.15	8.3	2.94	4.93	21.4	1.04	1.01	3.5
	2825	10/28/76	1730													
		10/28/76	2330													
		10/29/76	0730													
		10/29/76	1530													
		10/29/76	2330													
		10/30/76	0730													
		10/30/76	1530													
		10/30/76	2330													
		11/01/76	1530													
		11/01/76	2330													
		11/02/76	0730													
		11/02/76	1530													

SOLID ANALYSES

RUN NC.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXIDATION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
615-2A	2825	11/02/76	2330													
		11/03/76	0730													
616-2A	2816	11/05/76	2330		17.61	15.45	0.90	20.21	1.60	4.9		3.16	4.5	1.24	1.14	8.0
		11/06/76	0730		22.32	20.45	1.50	27.06	1.43	8.8	3.33	4.78	5.5	1.19	1.10	6.9
		11/06/76	1530		23.15	19.54	2.26	26.68	0.99	8.0		4.33	8.5	1.24	1.07	13.9
					23.16	19.54	2.79	27.21	1.10				10.2	1.22	1.07	11.7
		11/06/76	2330		25.77	20.26	7.12	32.44	2.97	7.8		3.42	21.9	1.13	1.17	-2.9
		11/07/76	0730		22.12	18.27	5.57	28.40	0.99	8.1	3.36	4.30	19.6	1.11	1.06	4.4
		11/07/76	1530		24.22	21.89	3.94	31.30	0.55	8.0		3.95	12.6	1.10	1.03	6.6
		11/07/76	2330		26.74	23.36	3.83	33.03	1.24	7.7		3.45	11.6	1.16	1.07	7.6
		11/08/76	0730		23.46	19.33	4.37	28.53	1.23	8.0	3.04	4.13	15.3	1.17	1.08	8.1
		11/08/76	1530		24.64	22.44	2.28	30.33	1.48	8.2		4.03	7.5	1.16	1.09	6.1
		11/08/76	2330		24.70	23.16	2.93	31.88	1.26	7.9		3.79	9.2	1.11	1.07	3.1
		11/09/76	0730		25.41	21.99	7.30	34.78	1.12	8.4	3.13	3.71	21.0	1.04	1.06	-1.5
		11/09/76	1530		19.50	20.26	1.14	26.46	1.70	8.0		4.59	[illegible]	1.05	1.12	-6.2
		11/09/76	2330		28.46	23.70	10.49	40.11	0.99	7.9		2.87	26.2	1.01	1.04	-3.2
		11/10/76	0730		24.93	19.15	10.74	34.67	1.52	7.8	2.80	3.41	31.0	1.03	1.08	-5.2
		11/10/76	1530		21.29	19.54	4.96	29.38	1.65	7.8		4.10	16.9	1.03	1.10	-5.5
		11/10/76	2330		26.60	19.32	12.32	36.47	0.91	7.7		3.15	33.8	1.04	1.05	-0.4
		11/11/76	0730		23.20	19.45	7.60	31.91	0.89	7.7	3.17	3.76	23.8	1.04	1.05	-1.2
		11/11/76	1730		19.01	19.90	1.11	25.98	1.26	8.0		4.70	4.3	1.04	1.09	-4.2
		11/11/76	2330		27.03	23.52	8.85	38.25	0.77	7.5		2.99	23.1	1.01	1.04	-2.8
		11/12/76	0730		30.74	24.56	11.91	42.61	1.14	8.2	2.46	2.60	28.0	1.03	1.05	-1.8
		11/12/76	1530		30.38	22.07	13.91	41.49	0.33	7.7		2.57	33.5	1.05	1.01	3.0
		11/12/76	2330		25.24	20.45	10.76	36.32	1.28	8.0		3.38	29.6	0.99	1.06	-7.3
		11/13/76	0730		26.56	21.46	9.84	36.66	0.87	8.7	2.55	3.59	26.8	1.03	1.04	-0.9
	2825	11/05/76	2330													
		11/06/76	0730													
		11/06/76	1530													
		11/06/76	2330													
		11/07/76	0730													
		11/07/76	1530													
		11/07/76	2330													
		11/08/76	0730													
		11/08/76	1530													
		11/08/76	2330													
		11/09/76	0730													
		11/09/76	1530													
		11/09/76	2330													
		11/10/76	0730													
		11/10/76	1530													
		11/10/76	2330													
		11/11/76	0730													
		11/11/76	1730													
		11/11/76	2330													

SOLID ANALYSES

RUN NO.	ANALYTICAL POINT	DATE	TIME	SOLID FLAG	CAO WT %	SO2 WT %	SO3 WT %	TOTAL SO3 WT %	CO2 WT %	SLURY SOLID WT %	ACID INSOL WT %	CALC INSOL WT %	OXI DAT ION %	STOIC RATIO (CA)	STOIC RATIO (CO3)	SOLID IONIC IMBAL %
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616-2A	2825	11/12/76	0730													
		11/12/76	1530													
		11/12/76	2330													
		11/13/76	0730													
617-2A	2816	11/15/76	1930		25.88	25.01	2.97	34.23	1.15	10.8		4.85	8.7	1.09	1.06	1.7
		11/15/76	2330		25.46	22.80	4.02	32.52	0.99	15.5		7.24	12.4	1.12	1.06	5.6
		11/16/76	0730		24.11	22.44	2.03	30.08	0.93	8.1	5.11	4.09	6.8	1.14	1.06	7.7
		11/16/76	1530		26.37	25.15	2.06	33.49	0.71	14.3		6.54	6.1	1.12	1.04	7.6
		11/16/76	2330		26.50	25.46	2.70	34.52	1.07	14.4		6.38	7.8	1.10	1.06	3.6
		11/17/76	0730		25.27	22.44	5.21	33.26	1.26	14.8	4.92	6.78	15.7	1.08	1.07	1.5
		11/17/76	1530		27.77	25.41	2.98	34.74	1.14	15.2		6.49	8.6	1.14	1.06	7.1
		11/17/76	2330		26.24	23.34	2.63	32.00	1.32	14.0		6.48	8.8	1.17	1.08	8.2
		11/18/76	0730		23.73	20.26	5.21	30.53	1.04	15.3	5.43	7.61	17.1	1.11	1.06	4.3
		11/18/76	1730		24.63	19.18	6.78	30.75	1.26	15.1		7.27	22.0	1.14	1.07	6.0
		11/18/76	2330		24.72	23.42	1.85	31.12	1.17	15.5		7.57	5.9	1.13	1.07	5.8
		11/19/76	0930		23.87	19.90	4.24	29.11	1.15	14.0	5.52	7.12	14.6	1.17	1.07	5.4
		11/19/76	1530		22.68	20.91	2.19	28.19	1.10	14.6		7.74	7.7	1.16	1.07	7.6
		11/19/76	2330		23.68	22.50	1.68	30.18	1.04	15.1		7.67	5.6	1.12	1.06	5.1
		11/20/76	0730		22.62	20.63	3.50	29.28	1.10	14.9	5.79	7.77	11.9	1.10	1.07	3.1
		11/20/76	1530		24.16	21.89	4.45	31.81	0.93	15.2		7.38	14.0	1.08	1.05	2.9
		11/20/76	2330		25.69	22.80	5.09	33.59	1.70	14.8		6.62	15.2	1.09	1.09	0.0
		11/21/76	0730		23.37	21.35	2.66	29.34	1.70	14.7	6.01	7.49	9.1	1.14	1.11	2.6
		11/21/76	1530		25.89	23.16	3.75	32.70	0.93	14.7		6.80	11.5	1.13	1.05	7.0
		11/21/76	2330		27.79	23.99	5.26	35.12	1.09	14.5		6.09	15.0	1.13	1.06	4.5
		11/22/76	0730		23.39	22.26	2.13	29.95	1.54	14.7	4.95	7.45	7.1	1.11	1.09	1.9
	2825	11/15/76	1930													
		11/15/76	2330													
		11/16/76	0730													
		11/16/76	1530													
		11/16/76	2330													
		11/17/76	0730													
		11/17/76	1530													
		11/17/76	2330													
		11/18/76	0730													
		11/18/76	1730													
		11/18/76	2330													
		11/19/76	0930													
		11/19/76	1530													
		11/19/76	2330													
		11/20/76	0730													
		11/20/76	1530													
		11/20/76	2330													
		11/21/76	0730													

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          SOLID ANALYSES

                                                                                                       OXI                 SOLID
                                                                           TOTAL            SLURY ACID  CALC       DAT  STOIC STOIC  IONIC
          ANALY                                                                                                                  
RUN      TICAL                            SOLID     CAO   SO2   SO3   SO3   CO2   SOLID INSOL INSOL     ION  RATIO RATIO  IMBAL
NO.      POINT  DATE      TIME  FLAG      WT %  WT %  WT %  WT %  WT %  WT %  WT %  WT %      %   (CA)  (CO3)     %
------- -----  --------- ----  --------  ----- ----- ----- ----- ----- ----- ----- -----   ----- ----- -----   -----
617-2A   2825  11/21/76  1530
               11/21/76  2330
               11/22/76  0730
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APPENDIX E

TEST RESULTS SUMMARY TABLES FOR THE VENTURI/SPRAY TOWER

Table E-1

SUMMARY OF LIME/MGO TESTS ON THE VENTURI/SPRAY TOWER SYSTEM

Run No.	629-1A	630-1A	631-1A	632-1A
Start-of-Run Date	4/28/76	5/12/76	5/18/76	5/28/76
End-of-Run Date	5/12/76	5/18/76	5/24/76	6/4/76
On Stream Hours	267	142	145	161
Gas Rate, acfm @ 330°F	35,000	35,000	35,000	35,000
Spray Tower Gas Vel, fps @ 125°F	9.4	9.4	9.4	9.4
Venturi/Spray Tower Liquor Rates, gpm	600/1400	600/1400	680/700	min. (~140)/1400
Spray Tower L/G, gal/mcf	50	50	25	50
Percent Solids Recirculated	7-10	8-9	7-10	8-9
Effluent Residence Time, min.	3	3	3	3
Solids Disposal System	Clarifier & Filter	Clarifier & Filter	Clarifier & Filter	Clarifier & Filter
Stoichiometric Ratio, moles Ca added/mole SO_2 absorbed	0.95-1.05$^{(a)}$	0.98-1.03$^{(b)}$	1.0-1.05$^{(c)}$	1.0-1.03$^{(d)}$
Avg % Lime Utilization, 100x moles SO_2 abs./mole Ca added	100$^{(a)}$	99$^{(b)}$	98$^{(c)}$	99$^{(d)}$
Inlet SO_2 Concentration, ppm	2300-3900	2400-3900	2300-3700	2200-3300
Percent SO_2 Removal	68-85	86-98	58-90	72-92
Scrubber Inlet pH Range	5.8-6.2	6.9-7.2	6.9-7.1	6.8-7.2
Scrubber Outlet pH Range	5.0-5.3	5.2-5.6	5.1-5.4	5.1-5.1
Percent Sulfur Oxidized	10-30	10-20	10-25	10-25
Loop Closure, % Solids Dischg.	52-60	50-56	53-59	52-56
Calculated Avg. % Sulfate Saturation in Scrubber Inlet Liquor @ 50°C	75	25	50	20
Total Dissolved Solids, ppm	15,000-23,000	17,000-20,000	18,000-25,000	1[illegible],000-22,000
Total ΔP Range, Excluding Mist Elimination System, in. H_2O	13.2-13.9	12.9-13.9	13.0-13.9	6.6-7.6
Venturi ΔP, in. H_2O	9	9	9	2.5-3.0 (Plug 100% open)
Mist Elimination System ΔP Range, in. H_2O	0.40-0.55	0.40-0.50	0.40-0.48	0.40-0.45
Mist Elimination System Configuration	3-pass, open-vane, 316 SS, chevron mist eliminator.	3-pass, open-vane, 316 SS chevron mist eliminator.	3-pass, open-vane, 316 SS chevron mist eliminator.	3-pass, open-vane, 316 SS, chevron mist eliminator
Absorbent	Lime slurried to 20 wt % with makeup water and added to scrubber downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt % with makeup water and added to scrubber downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt % with makeup water and added to scrubber downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt % with makeup water and added to scrubber downcomer. MgO dry fed to EHT.
Mist Eliminator Washing Scheme	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min (at 0.5 gpm/ft^2) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft^2 for 6 min/4 hrs.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min (at 0.5 gpm/ft^2) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft^2 for 6 min/4 hrs.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min (at 0.5 gpm/ft^2) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft^2 for 6 min/4 hrs.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min (at 0.5 gpm/ft^2) with 76 min off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft^2 for 6 min. every 4 hours.
Scrubber Internals	All nozzles on 4 headers sprayed downward. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	All nozzles on 4 headers sprayed downward. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	All nozzles on top 2 headers sprayed downward. 7 nozzles/header. Bottom 2 headers turned off.	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.
System Changes Before Start of Run	System cleaned. No changes.	No changes. No cleaning.	No changes. No cleaning.	No changes. No cleaning.
Method of Control	Scrubber inlet pH controlled at 6.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.	Scrubber inlet pH controlled at 7.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm	Scrubber inlet pH controlled at 7.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm	Scrubber inlet pH controlled at 7.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ppm
Run Philosophy	First longer term lime/MgO run. Selected for good SO_2 removal, reliable mist elim. performance and sulfate unsaturated operation.	Determine effect of increased pH on SO_2 removal and sulfate saturation.	Determine effect of reduced spray tower L/G on SO_2 removal and sulfate saturation.	To observe the effect of operating with the spray tower only on percent SO_2 removal and sulfate saturation. Compare with Run 630-1A.
Results	SO_2 removal averaged only 75% at 100% lime utilization. Sulfate saturation averaged 75%. The mist eliminator was 2% restricted at the end of run. (a) Total stoich. ratio for Ca & Mg is 1.00-1.05 (avg. alkali util. = 98%)	SO_2 removal improved from 75% to 92% average (and lime utilization dropped from 100 to 99 percent) by increasing the pH to 7.0 for this run from 6.0 during Run 629-1A. Sulfate saturation was 25%. Mist eliminator restriction reduced by 1%. (b) Total stoich. ratio for Ca & Mg is 1.01-1.06 (avg. alkali util. = 97%)	SO_2 removal averaged 74% (vs. 92% for Run 630-1A). Average percent sulfate saturation increased from 25% to 50%. Mist eliminator remained 1% restricted. (c) Total stoich. ratio for Ca & Mg is 1.03-1.09 (avg. alkali util. = 94%)	SO_2 removal averaged 82% (vs. 92% for Run 630-1A). Average percent sulfate saturation decreased slightly from 25% to 20%. Mist eliminator restriction at end of run was <1%. (d) Total stoich. ratio for Ca & Mg is 1.04-1.07 (avg. alkali util. = 95%).

Table E-1 (continued)

SUMMARY OF LIME/MGO TESTS ON THE VENTURI/SPRAY TOWER SYSTEM

Run No.	633-1A	
Start-of-Run Date	6/9/76	
End-of-Run Date	6/14/76	
On Stream Hours	212	
Gas Rate, acfm @ 330°F	25,000	
Spray Tower Gas Vel. fps @ 125°F	6.7	
Venturi Liquor Rate, gpm	min. (~140)	
Venturi L/G, gal/mcf	~7.0	
Spray Tower Liquor Rate, gpm	1400	
Spray Tower L/G, gal/mcf	70	
Percent Solids Recirculated	8-9	
Effluent Residence Time, min	1	
Solids Disposal System	Clarifier & Filter	
Stoichiometric Ratio, moles Ca added/mole SO_2 absorbed	0.97-1.05[a]	
Avg. % Lime Utilization, 100 x moles SO_2 abs./mole Ca added	99[a]	
Inlet SO_2 Concentration, ppm	2500-3400	
Percent SO_2 Removal	88-98	
Scrubber Inlet pH Range	6.9-7.2	
Scrubber Outlet pH Range	5.3-5.8	
Percent Sulfur Oxidized	9-20	
Loop Closure, % Solids Dischg.	49-53	
Calculated Avg % Sulfate Saturation in Scrubber Inlet Liquor @ 50°C	15	
Total Dissolved Solids, ppm	17,000-20,000	
Total ΔP Range, Excluding Mist Elimination System, in. H_2O	3.4-4.4	
Venturi ΔP, in. H_2O	1.6-2.0 (Plug 100% open)	
Mist Elimination System ΔP Range, in. H_2O	0.21-0.24	
Mist Elimination System Configuration	3-pass, open-vane, 316 SS, chevron mist eliminator	
Absorbent	Lime slurried to 20 wt % with makeup water and added to scrubber downcomer. MgO dry fed to EHT.	
Mist Eliminator Washing Scheme	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min (at 0.5 gpm/ft^2) with 76 min off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft^2 for 6 min. every 4 hours.	
Scrubber Internals	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	
System Changes Before Start of Run	No changes. No cleaning.	
Method of Control	Scrubber inlet pH controlled at 7.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm } Cl^-)}{2.92})$ ppm.	
Run Philosophy	To observe the effect on percent SO_2 removal and sulfate saturation of lower gas rate (higher L/G) during spray tower operation only (cf. 632-1A).	
Results	SO_2 removal averaged 93% (cf. 82% in 632-1A) and sulfate saturation was 15% (cf. 20% in 632-1A). [a] Total stoich. ratio for Ca & Mg is 1.00-1.09 (avg. alkali util. = 96%).	

Table E-2

SUMMARY OF FLY ASH-FREE LIMESTONE RUN 718-1A

Run No.	718-1A	
Start-of-Run Date	7/3/76	
End-of-Run Date	7/15/76	
On Stream Hours	235	
Gas Rate, acfm @ 330°F	35,000	
Spray Tower Gas Vel, fps @ 125°F	9.4	
Venturi Liquor Rate, gpm	600	
Venturi L/G, gal/mcf	21	
Spray Tower Liquor Rate, gpm	1400	
Spray Tower L/G, gal/mcf	50	
Percent Solids Recirculated	7-9	
Effluent Residence Time, min.	12	
Solids Disposal System	Clarifier & Filter	
Stoichiometric Ratio, moles Ca added/mole SO_2 absorbed	1.20-1.35	
Avg. % Limestone Utilization, 100x moles SO_2 abs. /mole Ca added	78	
Inlet SO_2 Concentration, ppm	2200-2600	
Percent SO_2 Removal	72-82	
Scrubber Inlet pH Range	5.8-6.0	
Scrubber Outlet pH Range	5.2-5.5	
Percent Sulfur Oxidized	15-30	
Loop Closure, % Solids Dischg.	50-61	
Calculated Avg. % Sulfate Saturation in Scrubber Inlet Liquor @ 50°C	120	
Total Dissolved Solids, ppm	8,800-10,000	
Total Δ P Range, Excluding Mist Elimination System, in. H_2O	12.6-13.4	
Venturi ΔP, in. H_2O	9	
Mist Elimination System Δ P Range, in. H_2O	0.47-0.52	
Mist Elimination System Configuration	3-pass, open-vane, 316 SS chevron mist eliminator	
Absorbent	Limestone slurried to 60 wt. % with makeup water and added to the scrubber downcomer.	
Mist Eliminator Washing Scheme	Top washed sequentially with makeup water. Each nozzle (6 total) on 3 minutes (at 0.5 gpm/sq ft) with 7 minutes off between nozzles. Bottom washed with makeup water at 1.5 gpm/sq ft for 4 minutes every hour.	
Scrubber Internals	All nozzles in 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	
System Changes Before Start of Run	No changes. No cleaning.	
Method of Control	Limestone stoichiometric ratio controlled at 1.2 moles Ca/mole SO_2 absorbed.	
Run Philosophy	To observe the effect of fly ash-free operation on sulfate saturation and system reliability (cf. Run 707-1A made with 15% solids with fly ash).	
Results	Sulfate saturation was 120% (cf. 45% for Run 707-1A). Mist eliminator 2% restricted at end of run.	

Table E-3

SUMMARY OF FLY ASH-FREE LIME TESTS (WITH AND WITHOUT MAGNESIUM) ON THE VENTURI/SPRAY TOWER SYSTEM

Run No.	634-1A	635-1A	636-1A	637-1A
Start-of-Run Date	6/19/76	7/16/76	7/26/76	8/6/76
End-of-Run Date	7/2/76	7/26/76	8/4/76	8/12/76
On Stream Hours	319	190	164	137
Gas Rate, acfm @ 330°F	35,000	35,000	25,000	35,000
Spray Tower Gas Vel, fps @ 125°F	9.4	9.4	6.7	9.4
Venturi Liquor Rate, gpm	600	600	600	600
Venturi L/G, gal/mcf	21	21	30	21
Spray Tower Liquor Rate, gpm	1400	1400	1400	1400
Spray Tower L/G, gal/mcf	50	50	70	50
Percent Solids Recirculated	4-5	8-9	8-9	8-9
Effluent Residence Time, min.	12	12	12	3
Solids Disposal System	Clarifier & Filter	Clarifier & Filter	Clarifier & Filter	Clarifier & Filter
Stoichiometric Ratio, moles Ca added/mole SO_2 absorbed	1.05-1.17	1.05-1.15	1.05-1.13	1.02-1.08
Avg. % Lime Utilization, 100 x moles SO_2 abs. /mole Ca added	90	91	92	95
Inlet SO_2 Concentration, ppm	1800-3400	1900-3200	2500-3100	2600-3300
Percent SO_2 Removal	68-84	62-90	80-90	67-75
Scrubber Inlet pH Range	7.8-8.2	7.9-8.2	7.8-8.2	7.6-8.2
Scrubber Outlet pH Range	4.7-5.2	4.6-5.2	4.9-5.1	4.75-5.0
Inlet O_2 Concentration, vol. %	6.5-9.5	6.8-9.3	6.5-9.5	6-9
Percent Sulfur Oxidized	3-18	10-30	8-25	8-22
Loop Closure, % Solids Dischg.	51-65	42-52	42-46	44-50
Calculated Avg. % Sulfate Saturation in Scrubber Inlet Liquor @ 50°C	100	95	85	80
Total Dissolved Solids, ppm	5800-9000	7800-10,400	6800-9800	6000-8000
Total ΔP Range, Excluding Mist Elimination System, in. H_2O	12.6-13.3	12.9-13.7	10.7-11.2	12.1-13.9
Venturi ΔP, in. H_2O	9	9	9	9
Mist Elimination System ΔP Range, in. H_2O	0.46-0.51	0.46-0.51	0.23-0.26	0.45-0.48
Mist Elimination System Configuration	3-pass, open-vane, 316L SS, chevron mist eliminator	3-pass, open-vane, 316L SS, chevron mist eliminator	3-pass, open-vane, 316L SS, chevron mist eliminator	3-pass, open-vane, 316L SS, chevron mist eliminator
Absorbent	Lime slurried to 20 wt % with makeup water and added to scrubber downcomer.	Lime slurried to 20 wt % with makeup water and added to scrubber downcomer.	Lime slurried to 20 wt % with makeup water and added to scrubber downcomer.	Lime slurried to 20 wt % with makeup water and added to scrubber downcomer.
Mist Eliminator Washing Scheme	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min. (at 0.5 gpm/ft^2) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft^2 for 6 min. every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min (at 0.5 gpm/ft^2) with 76 min.off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft^2 for 6 min. every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min (at 0.5 gpm/ft^2) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft^2 for 6 min. every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min (at 0.5 gpm/ft^2) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft^2 for 6 min. every 4 hours.
Scrubber Internals	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.
System Changes Before Start of Run	No changes. Clarifier and scrubber cleaned before run.	No changes. No cleaning.	No changes. No cleaning.	No changes. No cleaning.
Method of Control	Scrubber inlet liquor pH controlled at 8.0±0.2.	Scrubber inlet liquor pH controlled at 8.0±0.2.	Scrubber inlet liquor pH controlled at 8.0±0.2.	Scrubber inlet liquor pH controlled at 8.0±0.2.
Run Philosophy	First run of a test series with fly ash-free flue gas to observe the effect of fly ash-free slurry (4% solids) on sulfate saturation and system reliability. Same run conditions as for Run 626-1A except for absence of fly ash during this run.	To observe the effect of increased percent solids recirculated (8% cf. 4% during 634-1A) on sulfate saturation.	To observe the effect of lower gas rate, i.e., higher L/G's (25,000 acfm cf. 35,000 acfm during 635-1A) on SO_2 removal and sulfate saturation.	To observe the effect of low residence time (3 min. compared with 12 min. during Run 635-1A) on sulfate saturation.
Results	No significant differences between the average results of Runs 634-1A and 626-1A. Range of percent sulfate saturation was wider for Run 634-1A than for Run 626-1A.	Average sulfate saturation was 95% this run, compared with 100% during 634-1A. Mist eliminator about 2% restricted at end of run.	SO_2 removal averaged 85% (cf. 76% for 635-1A). Average sulfate saturation was 85% (cf. 95% for 635-1A). Mist eliminator was 1% restricted at end of run (1823 hours of operation since last mist eliminator cleaning).	SO_2 removal averaged 71% (cf. 76% for 635-1A) and lime utilization averaged 95% this run and 91% during 635-1A. Average sulfate saturation was 80% (cf. 95% for Run 635-1A). Mist eliminator was 1% restricted at end of run, no increase in restriction for the run.

Table E-3 (continued)

SUMMARY OF FLY ASH-FREE LIME TESTS (WITH AND WITHOUT MAGNESIUM) ON THE VENTURI/SPRAY TOWER SYSTEM

Run Number	638-1A	639-1A	640-1A	641-1A
Start-of-Run Date	8/16/76	8/24/76	9/2/76	9/9/76
End-of-Run Date	8/24/76	9/1/76	9/9/76	9/14/76
On Stream Hours	174	183	157	120
Gas Rate, acfm @ 330°F	35,000	35,000	35,000	35,000
Spray Tower Gas Vel, fps @ 125°F	9.4	9.4	9.4	9.4
Venturi Liquor Rate, gpm	600	600	600	min. (~140)
Venturi L/G, gal/mcf	21	21	21	~5.0
Spray Tower Liquor Rate, gpm	1400	1400	1400	1400
Spray Tower L/G, gal/mcf	50	50	50	50
Percent Solids Recirculated	4-5	4-5	7.7-8.8	7.9-8.5
Effluent Residence Time, min.	3	3	3	3
Solids Disposal System	Clarifier & Filter	Clarifier & Filter	Clarifier & Filter	Clarifier & Filter
Stoichiometric Ratio, moles Ca added/mole SO_2 absorbed	1.02-1.10	1.00-1.04[a]	1.02-1.05[b]	1.00-1.05[c]
Avg % Lime Utilization, 100x moles SO_2 abs./mole Ca added	94	98[a]	97[b]	98[c]
Inlet SO_2 Concentration, ppm	2000-3000	2200-3100	2500-3400	2500-2900
Percent SO_2 Removal	72-86	73-89	74-86	94-98
Scrubber Inlet pH Range	7.8-8.2	6.9-7.1	6.9-7.2	6.85-7.15
Scrubber Outlet pH Range	4.8-5.1	5.05-5.3	5.1-5.2	5.2-5.8
Inlet O_2 Concentration, vol. %	6.5-9.5	8.0-9.5	7-8.5	9.5-10
Percent Sulfur Oxidized	8-25	15-40	18-30	9-12
Loop Closure, % Solids Dischg.	47-59	44-54	48-51	45-50
Calculated Avg % Sulfate Saturation in Scrubber Inlet Liquor @ 50°C	120	105	85	6
Total Dissolved Solids, ppm	7900-9100	15,600-17,600	14,200-16,600	15,800-17,800
Total ΔP Range, Excluding Mist Elimination System, in. H_2O	12.4-13.0	12.6-13.8	13.2-13.6	6.4-7.2
Venturi ΔP, in. H_2O	9	9	9	3.4-3.7 (Plug 100% open)
Mist Elimination System ΔP Range, in. H_2O	0.45-0.48	0.47-0.59	0.45-0.52	0.48-0.51
Mist Elimination System Configuration	3-pass, open-vane, 316L SS, chevron mist eliminator	3-pass, open-vane, 316L SS, chevron mist eliminator	3-pass, open-vane, 316L SS, chevron mist eliminator	3-pass, open-vane, 316L SS, chevron mist eliminator
Absorbent	Lime slurried to 20 wt % with makeup water and added to scrubber downcomer.	Lime slurried to 20 wt % with makeup water and added to scrubber downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt % with makeup water and added to scrubber downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt % with makeup water and added to scrubber downcomer. MgO dry fed to EHT.
Mist Eliminator Washing Scheme	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min. (at 0.5 gpm/ft²) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft² for 6 min. every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min. (at 0.5 gpm/ft²) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft² for 6 min. every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min. (at 0.5 gpm/ft²) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft² for 6 min. every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min. (at 0.5 gpm/ft²) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft² for 6 min. every 4 hours.
Scrubber Internals	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.
System Changes Before Start of Run	No changes. No cleaning.	No changes. No cleaning.	Mist eliminator cleaned. No other changes.	Mist eliminator cleaned. No other changes.
Method of Control	Scrubber inlet liquor pH controlled at 8.0±0.2.	Scrubber inlet liquor pH controlled at 7.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm	Scrubber inlet liquor pH controlled at 7.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm	Scrubber inlet liquor pH controlled at 7.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm
Run Philosophy	To observe the effect of low percent solids recirculated (4% cf. 8% during Run 637-1A). Other run conditions the same as Run 637-1A.	The first fly ash-free lime test with MgO addition. To compare with Run 630-1A at same conditions but with fly ash and 8% solids in recirculating slurry.	To observe the effect of a higher percent solids recirculated (8% cf. 4% for Run 639-1A) on sulfate saturation. Other run conditions the same as for Run 639-1A.	To observe the effect of spray tower-only operation on SO_2 removal and sulfate saturation, in comparison with Run 640-1A.
Results	SO_2 removal averaged 79% (cf. 71% for 637-1A) and lime utilization averaged 94% (cf. 95% for 637-1A) at an average SO_2 inlet concentration of 2500 ppm (cf. 3000 ppm for 637-1A). The mist eliminator was 1% restricted at the end of the run, 2134 hours since last mist eliminator cleaning.	SO_2 removal averaged 81% (cf. 92% for 630-1A). Sulfate saturation was 105% (cf. 25% for 630-1A). Mist eliminator was 10% restricted at end of run, whereas restriction during 630-1A decreased from 2 to 1%. [a] Total stoich. ratio for Ca & Mg is 1.02-1.06 (avg. alkali util. = 96 %).	Sulfate saturation averaged 85% (cf. 105% for 639-1A). The mist eliminator was 5% restricted at the end of the run. [b] Total stoich. ratio for Ca & Mg is 1.04-1.07 (avg. alkali util. = 95%).	SO_2 removal averaged 96% (cf. 80% for Run 640-1A). Sulfate saturation averaged 6% (cf. 85% for Run 640-1A). The mist eliminator was < 1% restricted at the end of the run. [c] Total stoich. ratio for Ca & Mg is 1.02-1.07 (avg. alkali util. = 96%).

Table E-3 (continued)

SUMMARY OF FLY ASH-FREE LIME TESTS (WITH AND WITHOUT MAGNESIUM) ON THE VENTURI/SPRAY TOWER SYSTEM

Run Number	642-1A	643-1A	
Start-of-Run Date	9/15/76	9/27/76	
End-of-Run Date	9/27/76	10/5/76	
On Stream Hours	249	191	
Gas Rate, acfm @ 330°F	35,000	35,000	
Spray Tower Gas Vel, fps @ 125°F	9.4	9.4	
Venturi Liquor Rate, gpm	min. (~ 140)	600	
Venturi L/G, gal/mcf	~ 5.0	21	
Spray Tower Liquor Rate, gpm	1050	1400	
Spray Tower L/G, gal/mcf	37	50	
Percent Solids Recirculated	7.3-8.7	7.6-8.6	
Effluent Residence Time, min.	3	3	
Solids Disposal System	Clarifier & Filter	Clarifier & Centrifuge	
Stoichiometric Ratio, moles Ca added/mole SO_2 absorbed	1.00-1.04[a]	1.00-1.05[b]	
Avg. % Lime Utilization, 100x moles SO_2 abs. /mole Ca added	98[a]	98[b]	
Inlet SO_2 Concentration, ppm	2300-3000	2200-2800	
Percent SO_2 Removal	62-78	97-99	
Scrubber Inlet pH Range	6.8-7.2	6.8-7.2	
Scrubber Outlet pH Range	4.9-5.3	5.5-6.0	
Inlet O_2 Concentration, vol. %	7.5-10.0	8-10	
Percent Sulfur Oxidized	5-23	14-21	
Loop Closure, % Solids Dischg.	45-57	41-46	
Calculated Avg. % Sulfate Saturation in Scrubber Inlet Liquor @ 50°C	45	10	
Total Dissolved Solids, ppm	16,400-22,000	14,400-17,800	
Total ΔP Range, Excluding Mist Elimination System, in. H_2O	6.5-7.5	12.7-13.3	
Venturi ΔP, in. H_2O	3.0-4.1 (Plug 100% open)	9	
Mist Elimination System ΔP Range, in. H_2O	0.48-0.51	0.41-0.48	
Mist Elimination System Configuration	3-pass, open-vane, 316L SS, chevron mist eliminator.	3-pass, open-vane, 316L SS, chevron mist eliminator.	
Absorbent	Lime slurried to 20 wt % with makeup water and added to scrubber downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt % with makeup water and added to scrubber downcomer. MgO dry fed to EHT.	
Mist Eliminator Washing Scheme	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min. (at 0.5 gpm/ft^2) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft^2 for 6 min. every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min. (at 0.5 gpm/ft^2) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft^2 for 6 min. every 4 hours.	
Scrubber Internals	Second header from bottom turned off. All nozzles on remaining 3 headers sprayed downwards. 7 nozzles/header on top 2 headers. 6 nozzles on bottom header.	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	
System Changes Before Start of Run	No cleaning. No changes.	No cleaning. No changes.	
Method of Control	Scrubber inlet liquor pH controlled at 7.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.	Scrubber inlet liquor pH controlled at 7.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.	
Run Philosophy	To observe the effect of lower spray tower slurry rate (1050 gpm cf. 1400 gpm for Run 641-1A) during spray tower-only operation on SO_2 removal and sulfate saturation. Other run conditions same as Run 641-1A.	The purpose of the run was to provide fly ash-free sludge to Aerospace Corp. for sludge fixing with dry fly ash. Run conditions chosen were identical to those for Run 640-1A except that the filter was replaced by centrifuge.	
Results	SO_2 removal averaged 70% (cf. 96% for Run 641-1A) and sulfate saturation averaged 45% (cf. 6% for Run 641-1A). The mist eliminator was 3% restricted at the end of the run. --- [a] Total stoich. ratio for Ca & Mg is 1.02-1.06 (avg. alkali util. = 96%).	SO_2 removal averaged 98% (cf. 80% for Run 640-1A), and sulfate saturation was 10% (cf. 85% for Run 640-1A). The mist eliminator restriction reduced from 3% to 1% during run. --- [b] Total stoich. ratio for Ca & Mg is 1.03-1.08 (avg. alkali util. = 95%).	

Table E-4

SUMMARY OF FLUE GAS CHARACTERIZATION TESTS ON THE VENTURI/SPRAY TOWER SYSTEM

Run Number	VFG-1A	VFG-1B[b]	VFG-1C	VFG-1D
Start-of-Run Date	10/10/76	10/20/76	10/29/76	11/2/76
End-of-Run Date	10/18/76	10/29/76	11/2/76	11/6/76
On Stream Hours	182	207	87	96
Gas Rate, acfm @ 330°F	35,000	35,000	35,000	20,000
Spray Tower Gas Vel., fps @ 125°F	9.4	9.4	9.4	5.4
Venturi Liquor Rate, gpm	600	600	600	600
Venturi L/G, gal/mcf	21	21	21	37
Spray Tower Liquor Rate, gpm	1400	1400	1400	1400
Spray Tower L/G, gal/mcf	50	50	50	87
Percent Solids Recirculated	7.8-9.1	7.8-8.6	8.1-9.3	7.6-8.6
Effluent Residence Time, min.	3	12	12	12
Solids Disposal System	Clarifier & Filter	Clarifier & Filter	Clarifier & Filter	Clarifier & Filter
Stoichiometric Ratio, moles Ca added/mole SO_2 absorbed	1.00-1.04[a]	1.06-1.09	1.05-1.20	1.10-1.25
Avg. % Lime Utilization, 100x moles SO_2 abs. /mole Ca added	98[a]	93	89	85
Inlet SO_2 Concentration, ppm	2700-3400	2900-3500	2400-3400	2800-3700
Percent SO_2 Removal	85-99	68-75	62-80	88-96
Scrubber Inlet pH Range	6.8-7.1	7.8-8.2	7.9-8.1	7.85-8.1
Scrubber Outlet pH Range	5.2-5.9	4.5-4.8	4.6-4.9	4.9-5.6
Inlet O_2 Concentration, vol. %	4.5-7.5	7-10	4.5-9	4-6.5
Percent Sulfur Oxidized	3-15	6-12	2-12	1-12
Loop Closure, % Solids Dischg.	48-57	42-62	53-60	51-57
Calculated Avg. % Sulfate Saturation in Scrubber Inlet Liquor @ 50°C	20	115	90	40
Total Dissolved Solids, ppm	13,600-17,600	7800-9000	7700-9600	6000-8200
Total ΔP Range, Excluding Mist Elimination System, in. H_2O	12.7-13.3	12.5-13.8	13.0-13.9	10.1-10.7
Venturi ΔP, in. H_2O	9	9	9	9
Mist Elimination System ΔP Range, in. H_2O	0.44-0.49	0.45-0.50	0.45-0.50	0.11-0.15
Mist Elimination System Configuration	3-pass, open-vane, 316L SS, chevron mist eliminator.	3-pass, open-vane, 316L SS, chevron mist eliminator.	3-pass, open-vane, 316L SS, chevron mist eliminator.	3-pass, open-vane, 316L SS, chevron mist eliminator.
Absorbent	Lime slurried to 20 wt. % with makeup water and added to scrubber downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt. % with makeup water and added to scrubber downcomer.	Lime slurried to 20 wt. % makeup water and added to scrubber downcomer.	Lime slurried to 20 wt. % with makeup water and added to scrubber downcomer.
Mist Eliminator Washing Scheme	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min. (at 0.5 gpm/ft^2) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft^2 for 6 min. every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min. (at 0.5 gpm/ft^2) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft^2 for 6 min. every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min. (at 0.5 gpm/ft^2) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft^2 for 6 min. every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min. (at 0.5 gpm/ft^2) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft^2 for 6 min. every 4 hours.
Scrubber Internals	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.
System Changes Before Start of Run	No changes. No cleaning.	Clarifier and hold tank (D-208) dumped and cleaned. No other changes or cleaning.	No changes. No cleaning.	No changes. No cleaning.
Method of Control	Scrubber inlet liquor pH controlled at 7.0 ± 0.2. Mg ion concentration in liquor controlled at $\left(2000 + \frac{\text{ppm Cl}^-}{2.92}\right)$ ppm	Scrubber inlet liquor pH controlled at 8.0 ± 0.2.	Scrubber inlet liquor pH controlled at 8.0 ± 0.2.	Scrubber inlet liquor pH controlled at 8.0 ± 0.2.
Run Philosophy	First run of a planned flue gas characterization test series. Conditions are same as Run 630-1A and were selected as typical run conditions with MgO addition and fly ash present.	Conditions are the same as Run 635-1A and were selected as typical fly ash-free run conditions with no MgO addition.	To observe the flue gas characteristics at the inlet and outlet of the scrubber under typical operating conditions with lime slurry (cf. Run 626-1A).	To observe the effect of low gas rate on flue gas characteristics at the inlet and outlet of the scrubber (cf. Run VFG-1C).
Results	SO_2 removal averaged 92% and mist eliminator remained <1% restricted. Some solids on I.D. fan damper at end of run. Sulfate saturation was 20%.	SO_2 removal averaged 72% and mist eliminator remained < 1% restricted. Sulfate saturation was 115%.	SO_2 removal averaged 71%, lime utilization 89%, at an average inlet SO_2 concentration of 2900 ppm (cf. 78%, 85% and 2500 ppm for Run 626-1A). Sulfate saturation averaged 90% (cf. 100% for Run 626-1A).	SO_2 removal averaged 92%, lime utilization 85%, at an average inlet SO_2 concentration of 3250 ppm. Sulfate saturation averaged 40%.

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[a] Total stoich. ratio for Ca & Mg is 1.03-1.07 (avg. alkali util. = 95%).

[b] This is the only fly ash-free run of this series.

Table E-4 (continued)

SUMMARY OF FLUE GAS CHARACTERIZATION TESTS ON THE VENTURI/SPRAY TOWER SYSTEM

Run Number	VFG-1E	VFG-1F	VFG-1G	VFG-1I
Start-of-Run Date	11/6/76	11/10/76	11/18/76	11/22/76
End-of-Run Date	11/10/76	11/18/76	11/21/76	11/27/76
On Stream Hours	96	124	71	117
Gas Rate, acfm @ 330°F	35,000	35,000	35,000	35,000
Spray Tower Gas Vel, fps @ 125°F	9.4	9.4	9.4	9.4
Venturi Liquor Rate, gpm	375	600	600	600
Venturi L/G, gal/mcf	13	21	21	21
Spray Tower Liquor Rate, gpm	1400	0	1400	1400
Spray Tower L/G, gal/mcf	50	0	50	50
Percent Solids Recirculated	8.0-8.9	7.6-9.0	7.2-8.8	14.6-15.9
Effluent Residence Time, min.	12	20	12	12
Solids Disposal System	Clarifier & Filter	Clarifier & Filter	Clarifier & Filter	Clarifier & Filter
Stoichiometric Ratio, moles Ca added/mole SO_2 absorbed	1.06-1.16	1.07-1.15	1.12-1.22	1.08-1.15
Avg % Lime Utilization, 100 x moles SO_2 abs./mole Ca added	90	90	85	90
Inlet SO_2 Concentration, ppm	2750-3600	3100-3800	3000-3400	2600-3500
Percent SO_2 Removal	64-76	16-28	79-86	70-86
Scrubber Inlet pH Range	7.7-8.25	7.8-8.1	7.8-8.3	7.8-8.2
Scrubber Outlet pH Range	4.5-5.1	4.4-4.8	4.9-5.2	4.6-5.0
Inlet O_2 Concentration, vol %	4.5-8	5-7	5-6	3.5-6.5
Percent Sulfur Oxidized	2-19	2-19	1-23	6-24
Loop Closure, % Solids Dischg.	45-63	59-64	51-54	52-55
Calculated Avg. % Sulfate Saturation in Scrubber Inlet Liquor @ 50°C	45	75	40	40
Total Dissolved Solids, ppm	5800-7600	7700-9100	8200-8500	6600-8600
Total ΔP Range, Excluding Mist Elimination System, in. H_2O	8.3-10.8	11.5-13.5	13.4-13.8	13.1-13.8
Venturi ΔP, in. H_2O	4.1-6.5 (Plug 100% open)	9	9	9
Mist Elimination System ΔP Range, in. H_2O	0.43-0.50	0.37-0.45	0.75-1.75	0.37-0.44
Mist Elimination System Configuration	3-pass, open-vane, 316L SS chevron mist eliminator.	3-pass, open-vane, 316L SS chevron mist eliminator.	3-pass, open vane, 316L SS chevron mist eliminator followed by a York demister.	3-pass, open vane, 316L SS chevron mist eliminator.
Absorbent	Lime slurried to 20 wt. % with makeup water and added to scrubber downcomer.	Lime slurried to 20 wt. % with makeup water and added to scrubber downcomer.	Lime slurried to 20 wt. % with makeup water and added to scrubber downcomer.	Lime slurried to 20 wt. % with makeup water and added to scrubber downcomer.
Mist Eliminator Washing Scheme	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min. (at 0.5 gpm/ft²) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft² for 6 min. every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min. (at 0.5 gpm/ft²) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft² for 6 min. every 4 hours.	Mist eliminator: Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min. (at 0.5 gpm/ft²) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft² for 6 min. every 4 hours. York demister: No washing.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min. (at 0.5 gpm/ft²) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft² for 6 min. every 4 hours.
Scrubber Internals	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	All nozzles on 4 spray headers turned off.	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	All nozzles on 4 headers sprayed downwards. 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.
System Changes Before Start of Run	No changes. No cleaning.	No changes. No cleaning.	No cleaning. Installed a York demister downstream of the chevron mist eliminator.	The York demister was removed before run. No cleaning.
Method of Control	Scrubber inlet liquor pH controlled at 8.0 ± 0.2.	Scrubber inlet liquor pH controlled at 8.0 ± 0.2.	Scrubber inlet liquor pH controlled at 8.0 ± 0.2.	Scrubber inlet liquor pH controlled at 8.0 ± 0.2.
Run Philosophy	To observe the effect of low slurry flow to the venturi (plug 100% open) on flue gas characteristics at the inlet and outlet of the scrubber (cf. Run VFG-1C).	To observe the effect of venturi-only operation on flue gas characteristics at the inlet and outlet of the scrubber (cf. Run VFG-1C).	To observe the effect of the addition of a York demister to the existing chevron mist eliminator on flue gas characteristics at the outlet of the scrubber (cf. Run VFG-1C).	To observe the effect of high percent solids recirculated on flue gas characteristics at the inlet and outlet of the scrubber (cf. Run VFG-1C).
Results	SO_2 removal averaged 70%, lime utilization 90%, at an average inlet SO_2 concentration of 3200 ppm. Sulfate saturation averaged 45%.	Venturi alone removed 22% of SO_2. The mist eliminator was entirely clean at the end of the run after a total of 1352 hours of operation without cleaning.	SO_2 removal averaged 82%, lime utilization 85%, at an average inlet SO_2 concentration of 3200 ppm (cf. 71%, 89%, and 2900 ppm for Run VFG-1C). The York demister was 30% restricted. The mist eliminator was <1% restricted at end of run.	The sulfate saturation averaged 40% (cf. 90% for Run VFG-1C).

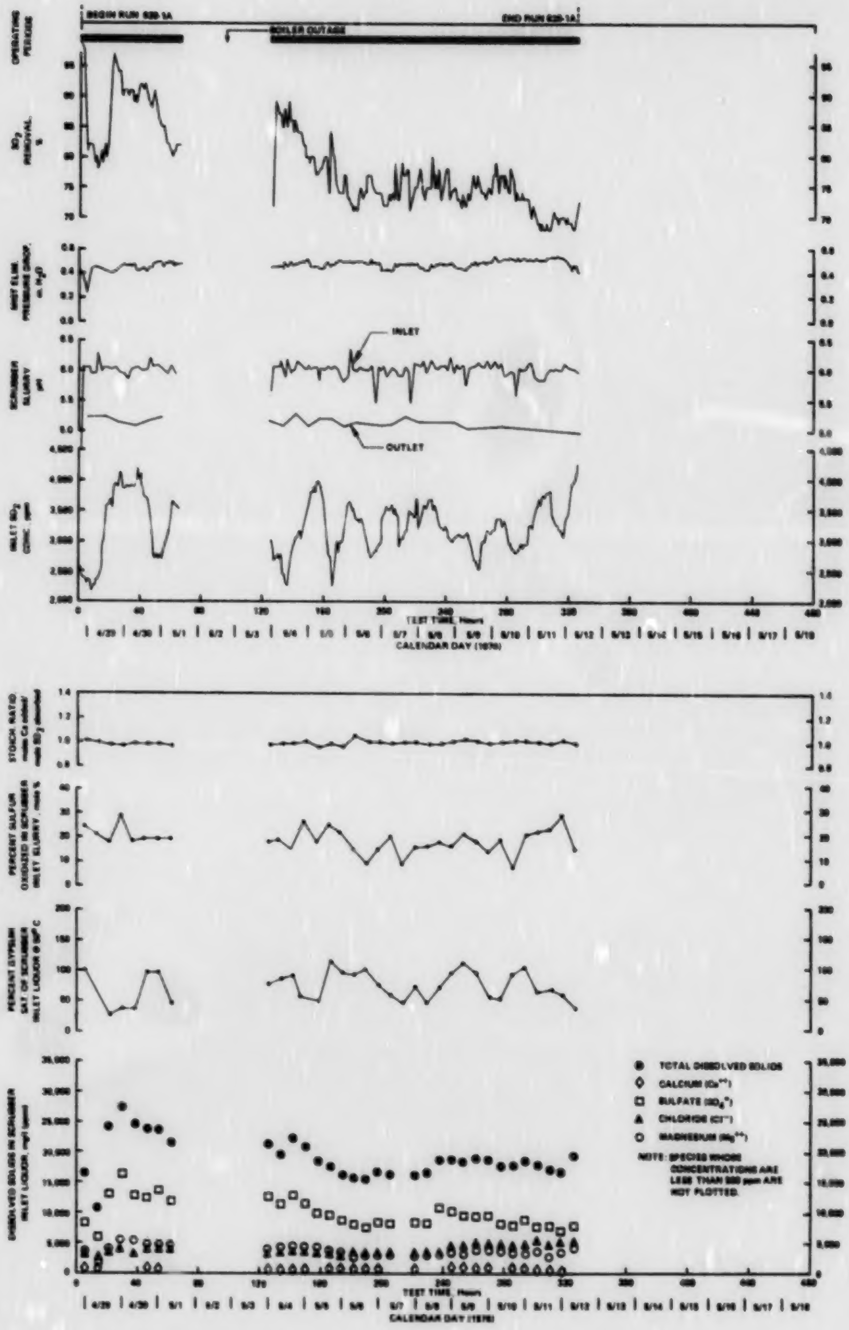
Table E-4 (continued)

SUMMARY OF FLUE GAS CHARACTERIZATION TESTS ON THE VENTURI/SPRAY TOWER SYSTEM

Run Number	VFG-1P	
Start-of-Run Date	11/27/76	
End-of-Run Date	12/4/76	
On Stream Hours	157	
Gas Rate, acfm @ 330°F	35,000	
Spray Tower Gas Vel., fps @125°F	9.4	
Venturi Liquor Rate, gpm	min. (~140)	
Venturi L/G, gal/mcf	5	
Spray Tower Liquor Rate, gpm	1400	
Spray Tower L/G, gal/mcf	50	
Percent Solids Recirculated	7.5-9.1	
Effluent Residence Time, min.	12	
Solids Disposal System	Clarifier & Filter	
Stoichiometric Ratio, moles Ca added/mole SO_2 absorbed	1.10-1.16	
Avg % Lime Utilization, 100 x moles SO_2 abs./mole Ca added	88	
Inlet SO_2 Concentration, ppm	2600-3800	
Percent SO_2 Removal	58-72	
Scrubber Inlet pH Range	7.85-8.15	
Scrubber Outlet pH Range	4.5-4.85	
Inlet O_2 Concentration, vol %	5-7.5	
Percent Sulfur Oxidized	2-18	
Loop Closure, % Solids Dischg.	55-60	
Calculated Avg % Sulfate Saturation in Scrubber Inlet Liquor @ 50°C	55	
Total Dissolved Solids, ppm	6900-8000	
Total ΔP Range, Excluding Mist Elimination System, in. H_2O	5.7-9.3	
Venturi ΔP, in. H_2O	1.4-5.7 (Plug 100% open)	
Mist Elimination System ΔP Range, in. H_2O	0.35-0.42	
Mist Elimination System Configuration	3-pass, open-vane, 316L SS chevron mist eliminator.	
Absorbent	Lime slurried to 20 wt.% with makeup water and added to scrubber downcomer.	
Mist Eliminator Washing Scheme	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 min. (at 0.5 gpm/ft^2) with 76 min. off between nozzles. Bottom washed with makeup water at 1.5 gpm/ft^2 for 6 min. every 4 hours.	
Scrubber Internals	All nozzles on 4 headers sprayed downwards, 7 nozzles/header on top 3 headers. 6 nozzles on bottom header.	
System Changes Before Start of Run	No changes. No cleaning.	
Method of Control	Scrubber inlet liquor pH controlled at 8.0 ± 0.2.	
Run Philosophy	To observe the effect of spray tower-only operation (min. venturi slurry flow rate with plug 100% open) on flue gas characteristics at the inlet and outlet of the scrubber (cf. Run VFG-1C).	
Results	SO_2 removal averaged 65%, lime utilization 88%, and inlet SO_2 concentration 3200 ppm. Sulfate saturation averaged 55%. Mist eliminator was entirely clean at the end of the run after a total 1697 hours of operation without cleaning.	

APPENDIX F

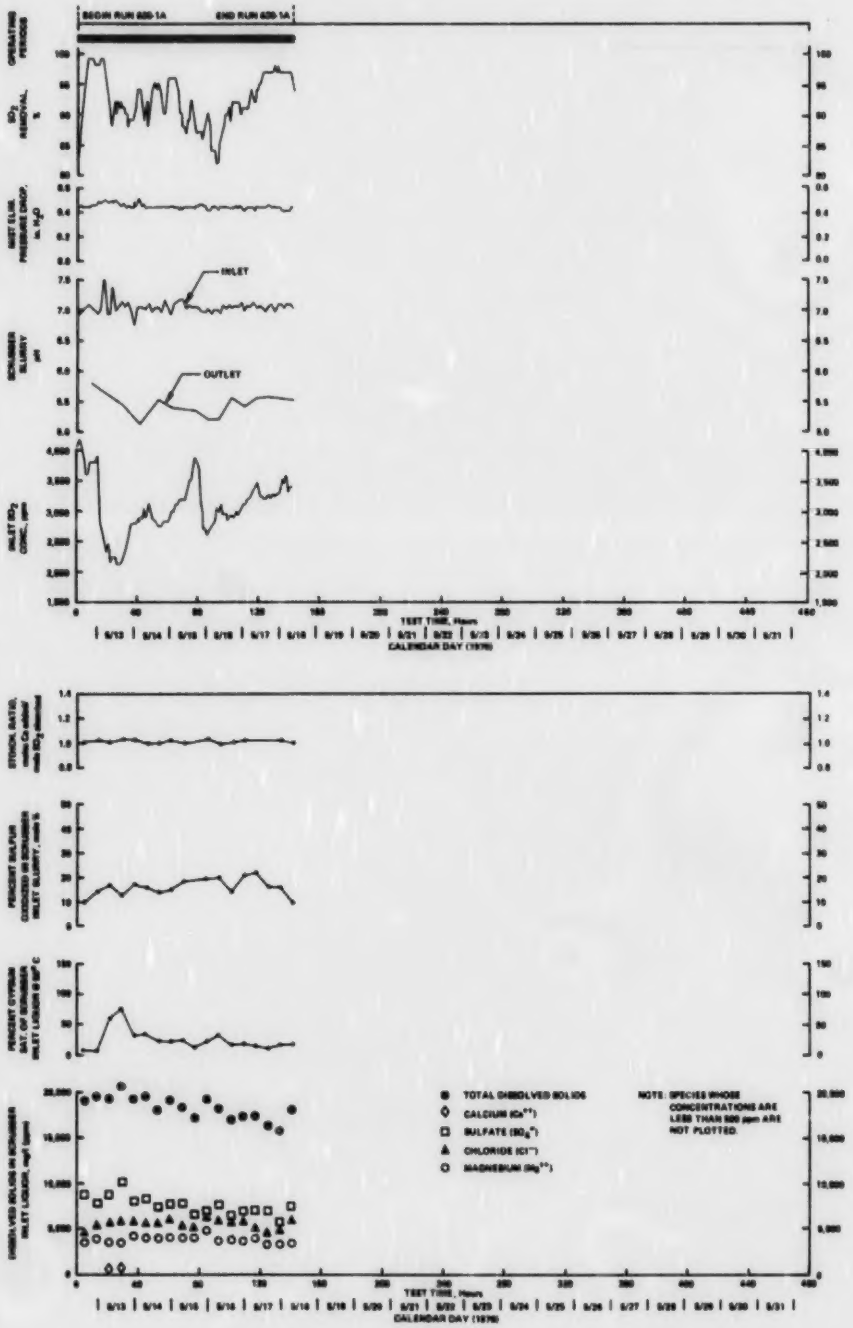
GRAPHICAL OPERATING DATA FROM THE VENTURI/SPRAY TOWER TESTS



Gas Rate = 35,000 acfm @ 330 °F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 1400 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 3 min

Percent Solids Recirculated = 7-10 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 13.2-13.9 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 52-60 wt %
Lime Addition to Downcomer and MgO
Addition to EHT

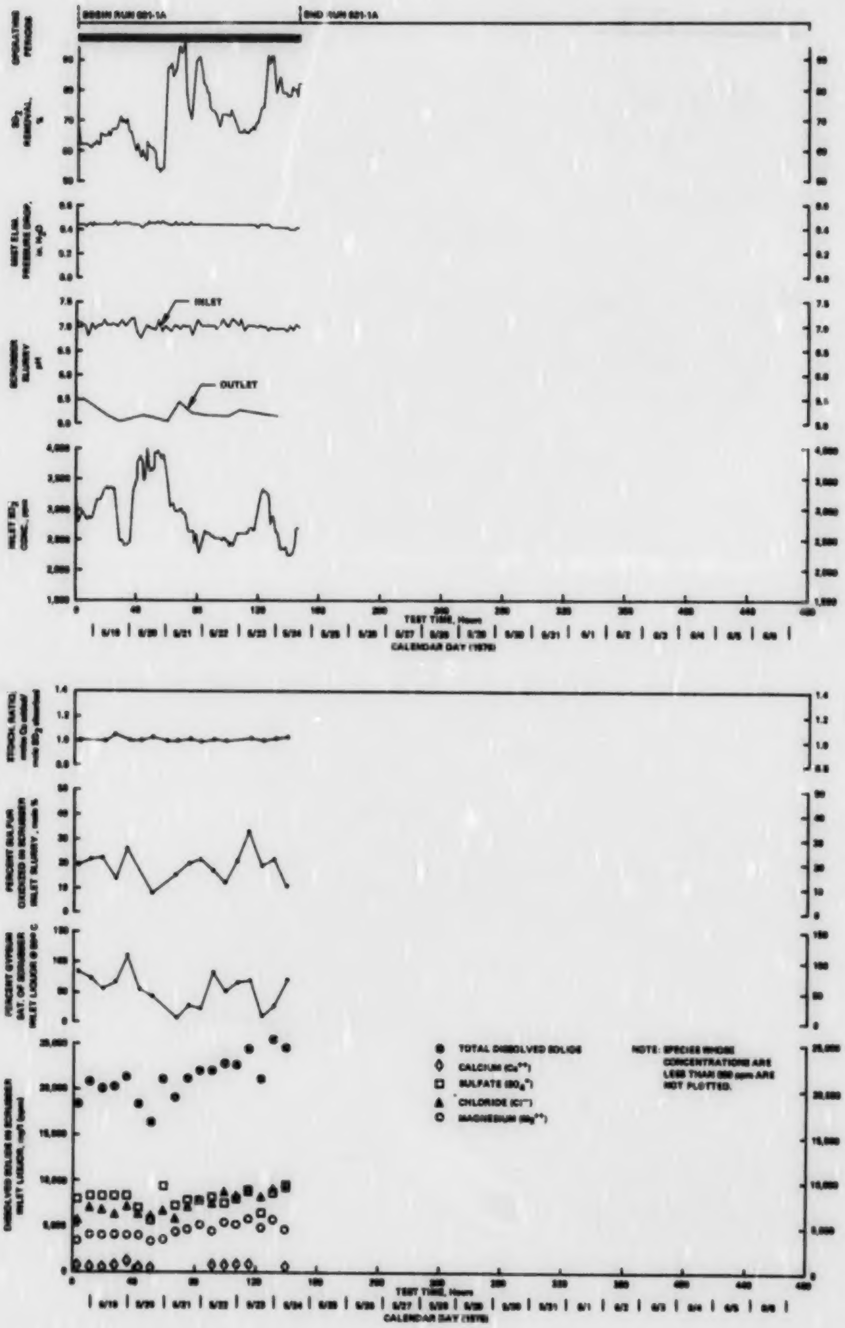
Figure F-1. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN 629-1A



Gas Rate = 35,000 acfm @ 330 °F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 1400 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 3 min

Percent Solids Recirculated = 8-9 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 12.0-13.0 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 50-58 wt %
Lime Addition to Downcomer and MgO
Addition to EHT

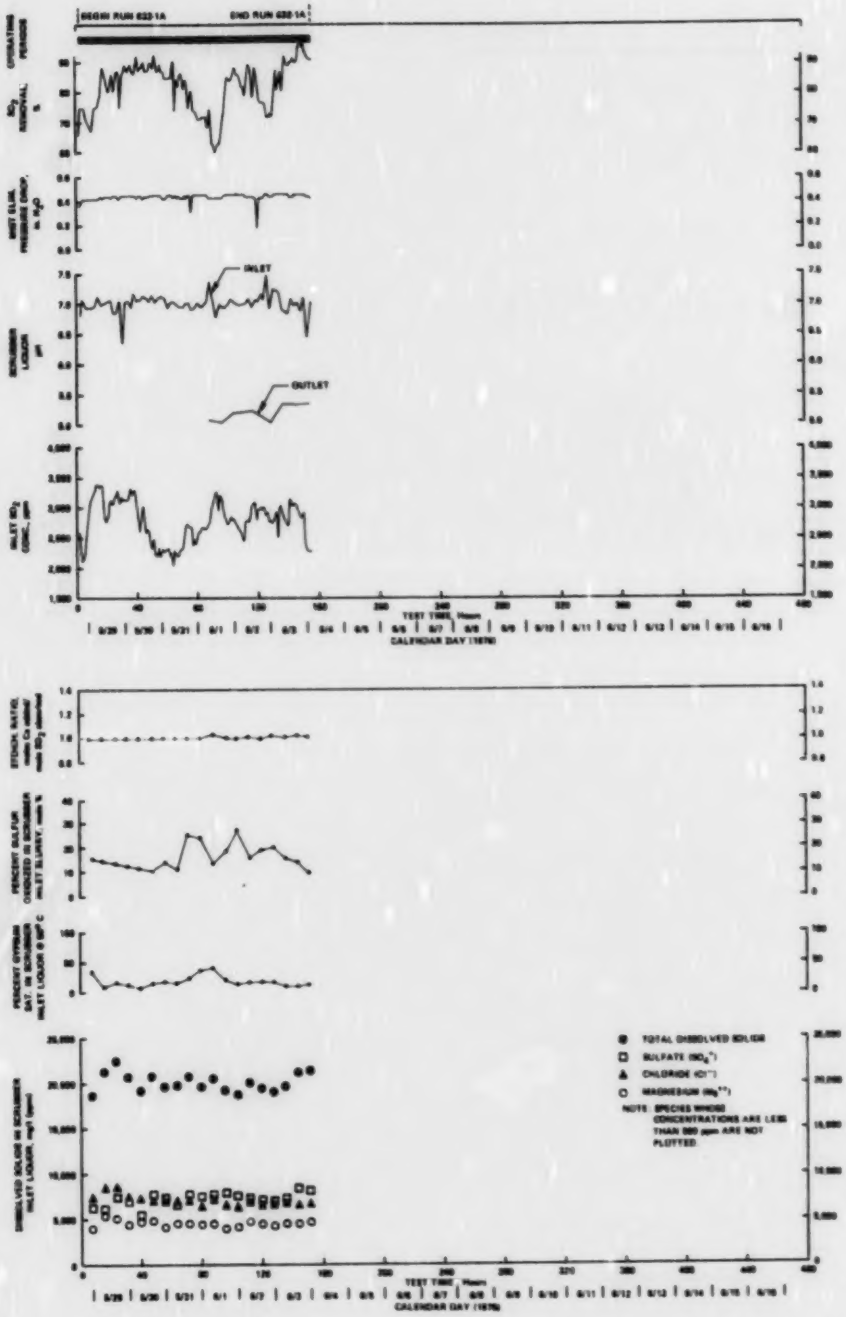
FigureF-2. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN 630-1A



Gas Rate = 35,000 acfm @ 330 °F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 700 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 25 gal/mcf
No. of Spray Headers = 2
EHT Residence Time = 3 min

Percent Solids Recirculated = 7-10 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim. = 13.0-13.5 in. H_2O
Discharge (Clarifier & Filter) Solids Concentration = 53-58 wt %
Lime Addition to Downcomer and MgO Addition to EHT

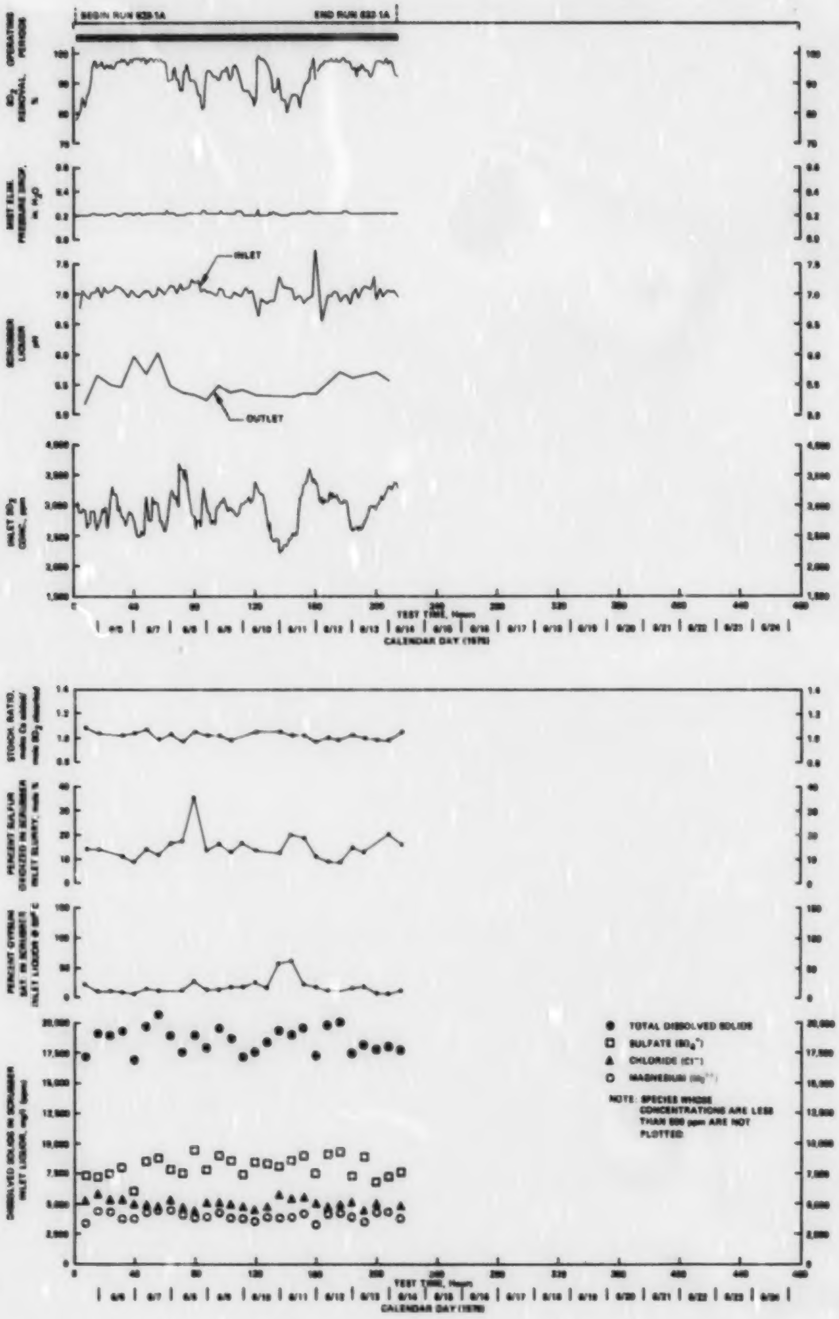
Figure F-3. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN 631-1A



Gas Rate = 35,000 acfm @ 330 °F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 140 gpm
Liquor Rate to Spray Tower = 1400 gpm
Venturi L/G = 5 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 3 min

Percent Solids Recirculated = 8-9 wt %
Venturi Pressure Drop = 2.5-3.0 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 6.6-7.6 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 52-66 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

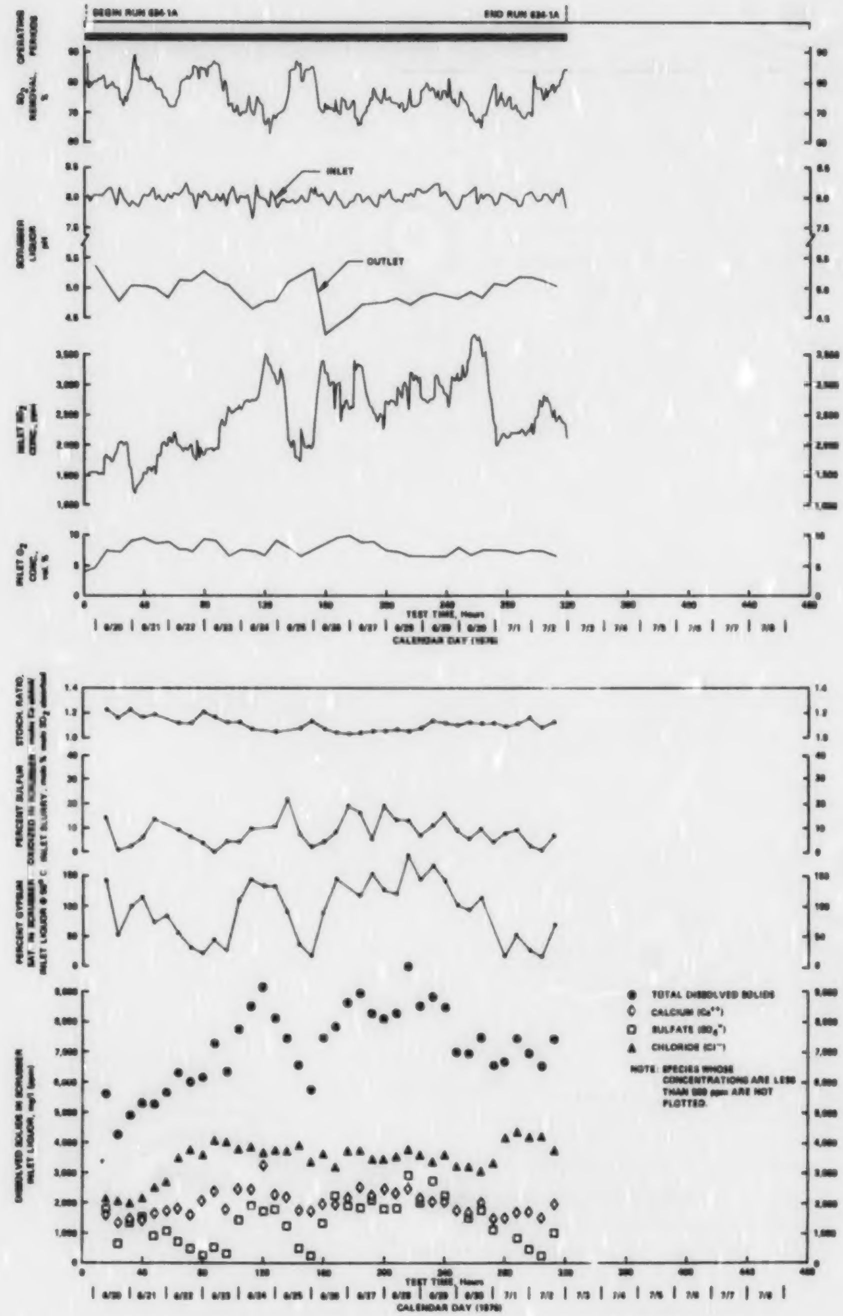
Figure F-4. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN 632-1A



Gas Rate = 25,000 acfm @ 330 °F
Spray Tower Gas Velocity = 6.7 ft/sec
Liquor Rate to Venturi = 140 gpm
Liquor Rate to Spray Tower = 1400 gpm
Venturi L/G = 7 gal/mcf
Spray Tower L/G = 70 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 3 min

Percent Solids Recirculated = 8-9 wt %
Venturi Pressure Drop = 1.6-2.0 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 3.4-4.4 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 48-53 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

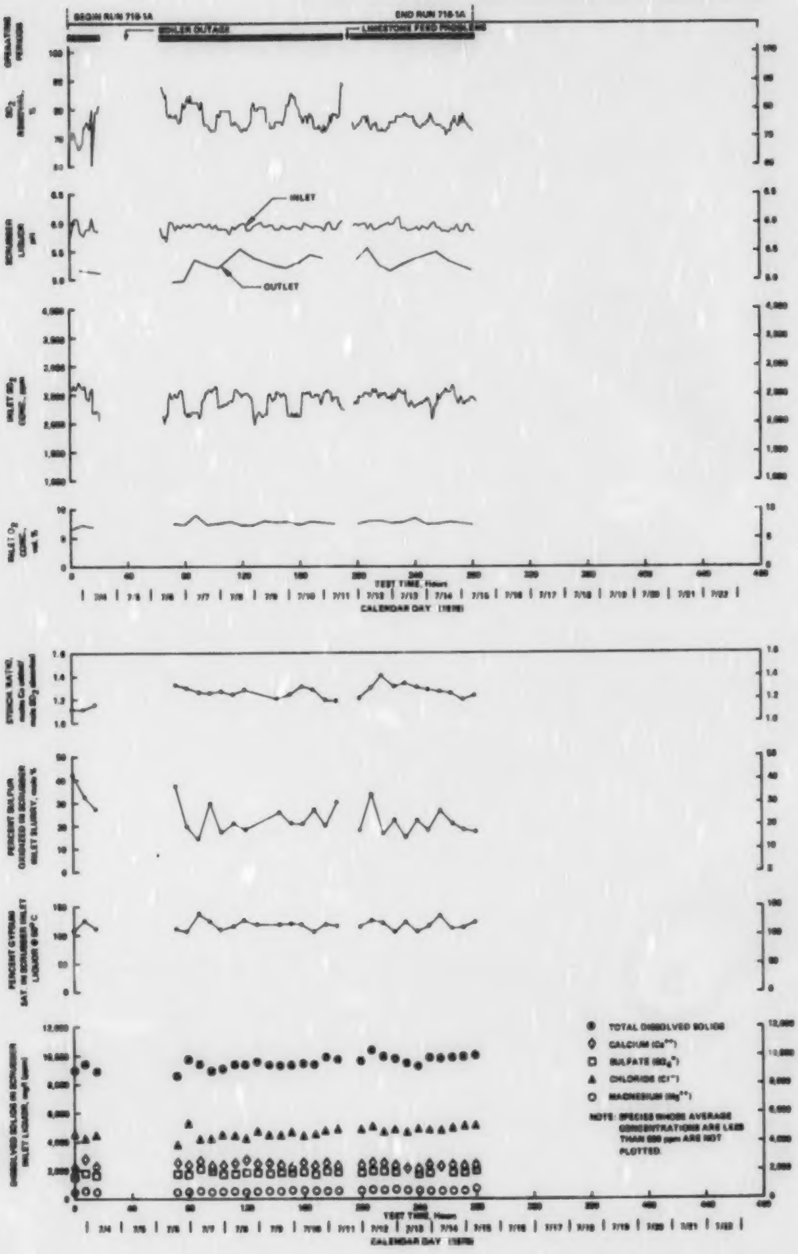
Figure F-5. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN 633-1A



Gas Rate = 35,000 acfm @ 330 °F
Spray Tower Gas Velocity = 8.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 1400 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 12 min

Percent Solids Recirculated = 4-5 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 12.0-13.3 in. H_2O
Mist Elim. Pressure Drop = 0.46-0.51 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 51-65 wt %
Lime Addition to Downcomer

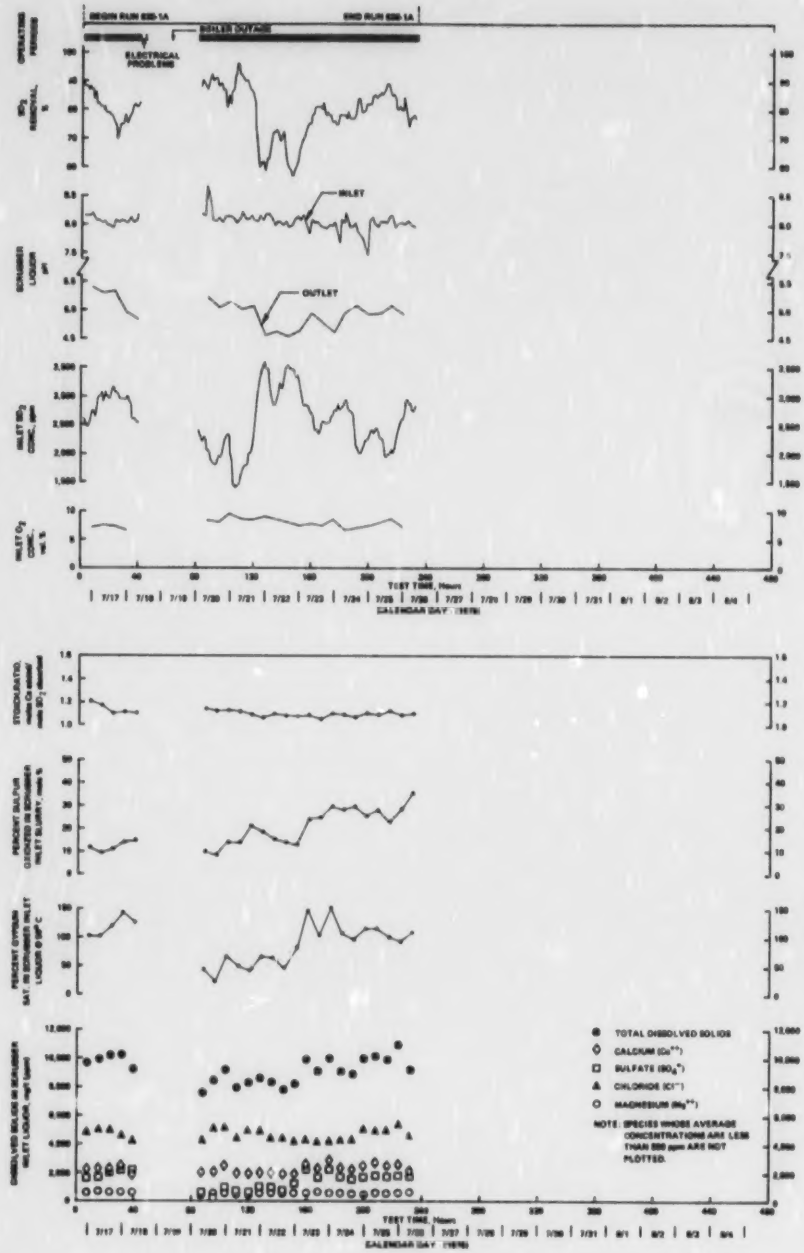
Figure F-6. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN 634-1A



Gas Rate = 35,000 acfm @ 330° F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 1400 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 12 min

Percent Solids Recirculated = 7-9 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 12.8-13.4 in. H_2O
Mist Elim. Pressure Drop = 0.47-0.52 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 56-61 wt %
Limestone Addition to Downcomer

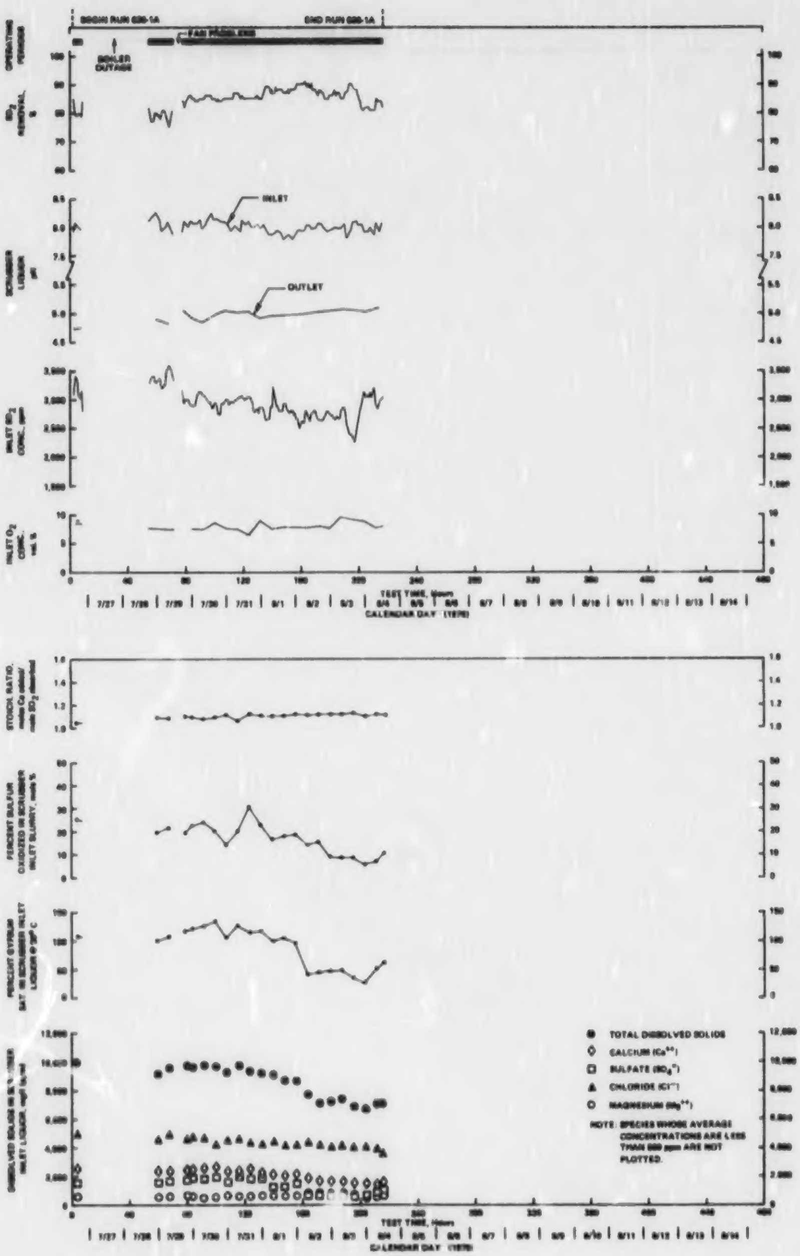
Figure F-7. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN 718-1A



Gas Rate = 35,000 acfm @ 330° F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 1400 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 12 min

Percent Solids Recirculated = 8-9 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 12.9-13.7 in. H_2O
Mist Elim. Pressure Drop = 0.48-0.61 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 42-52 wt %
Lime Addition to Downcomer

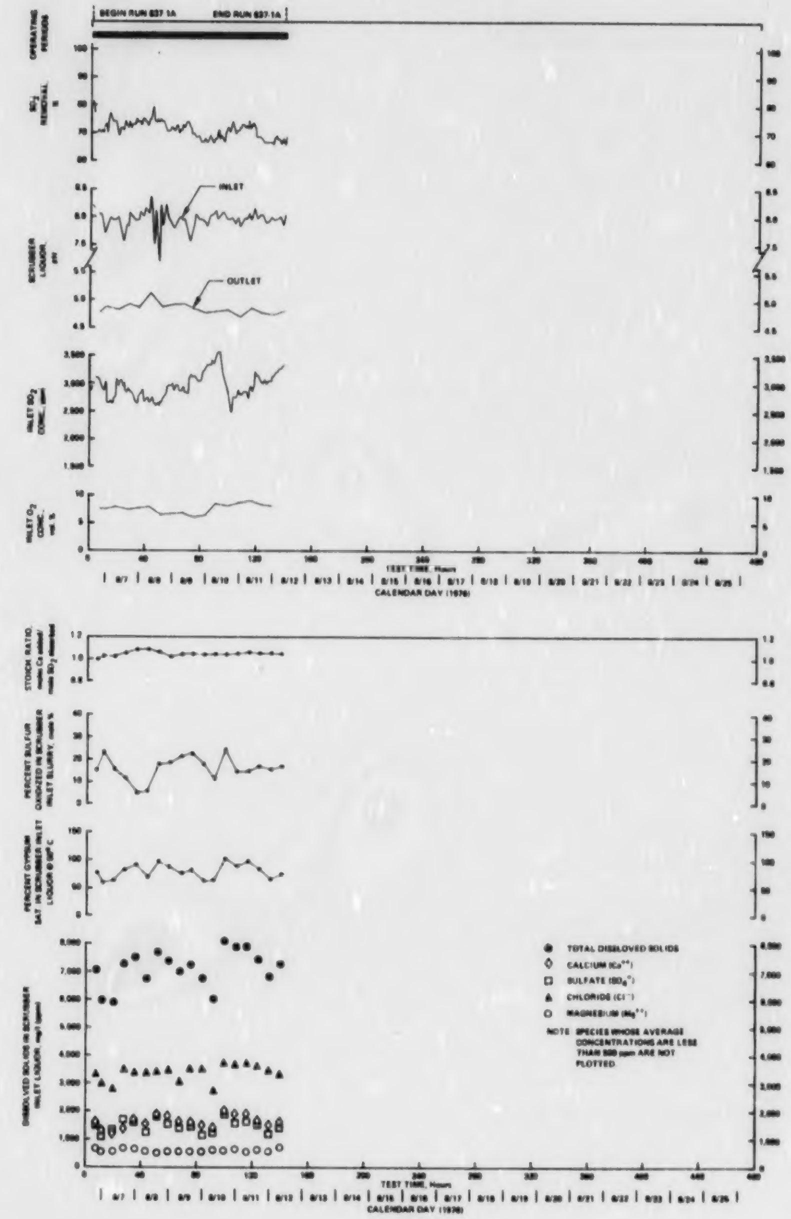
Figure F-8. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN 635-1A



Gas Rate = 25,000 acfm @ 330° F
Spray Tower Gas Velocity = 8.7 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 1400 gpm
Venturi L/G = 30 gal/mcf
Spray Tower L/G = 70 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 12 min

Percent Solids Recirculated = 8-9 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 10.7-11.2 in. H_2O
Mist Elim. Pressure Drop = 0.23-0.28 in. H_2O
Discharge (Clarifier & Centrifuge) Solids
Concentration = 42-46 wt %
Lime Addition to Downcomer

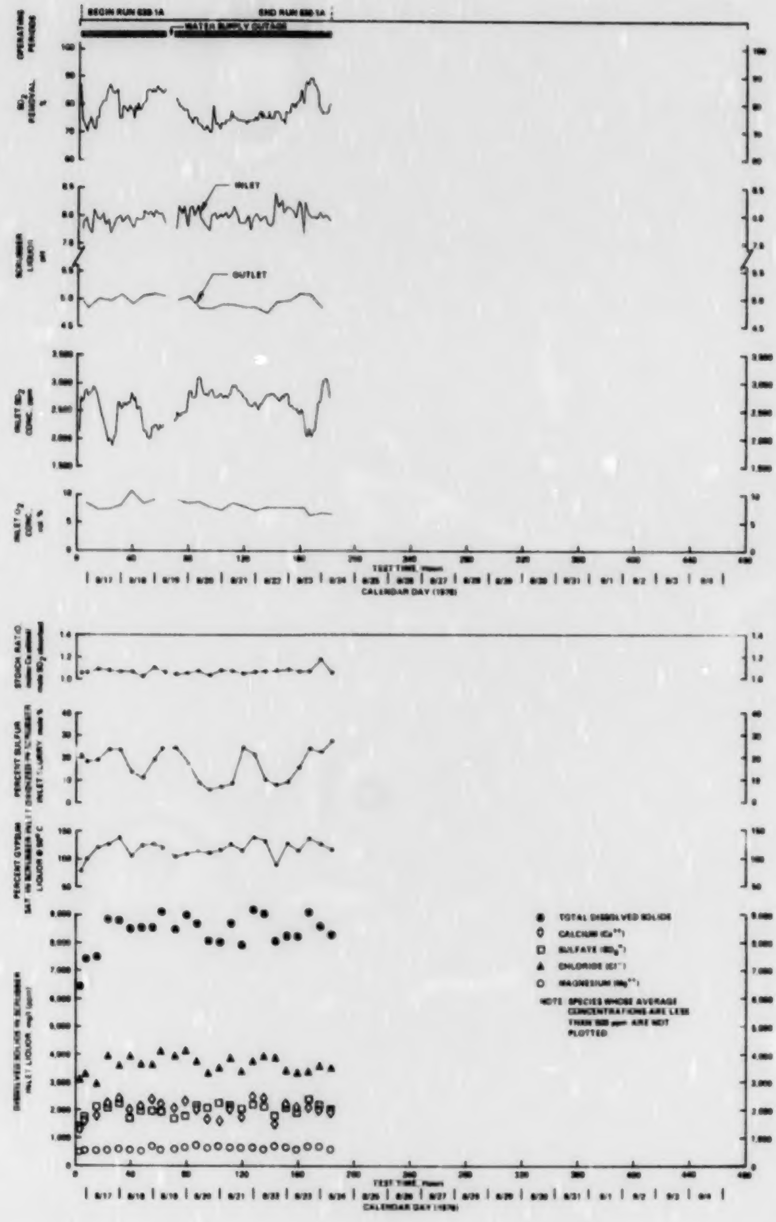
Figure F-9. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN 636 - 1A



Gas Rate = 35,000 acfm @ 330° F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 1,400 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 3 min

Percent Solids Recirculated = 8-9 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 12.1-13.9 in. H_2O
Mist Elim. Pressure Drop = 0.45-0.48 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 44-50 wt %
Lime Addition to Downcomer

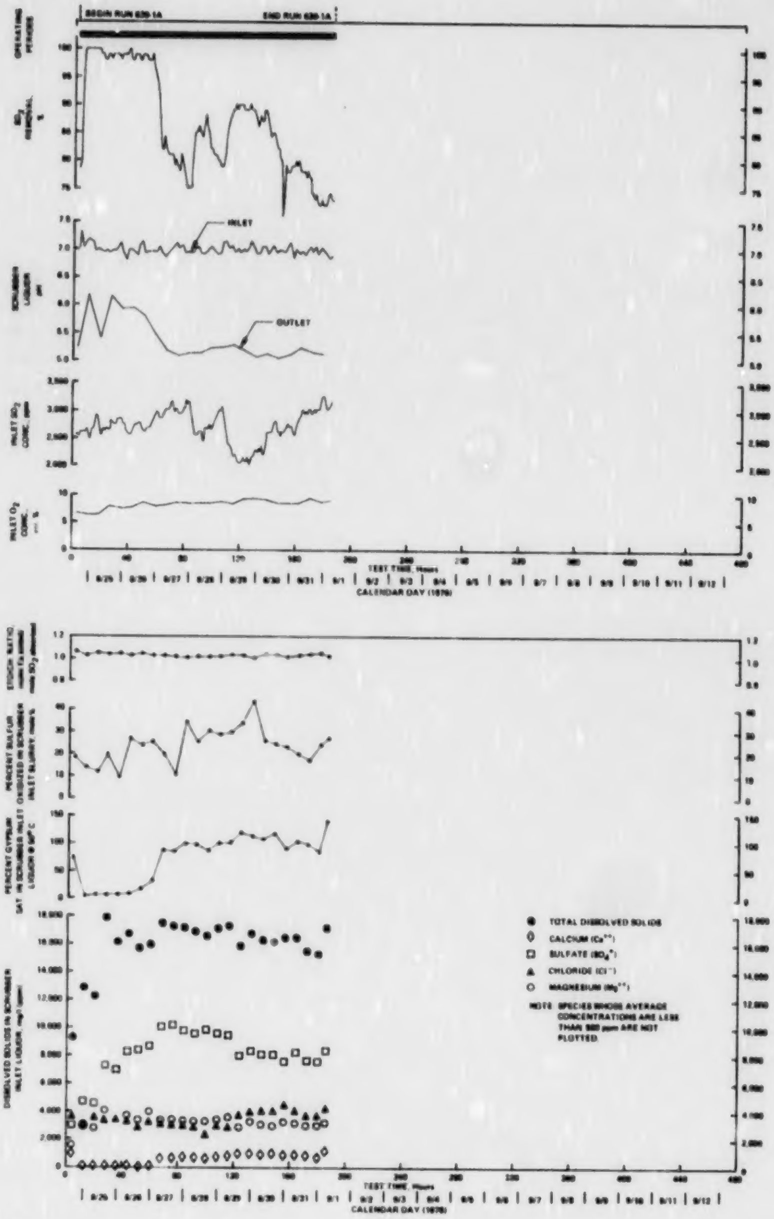
Figure F-10. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN 637 - 1A



Gas Rate = 35,000 acfm @ 330° F
Spray Tower Gas Velocity = 8.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 1,400 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 3 min

Percent Solids Recirculated = 4-5 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 12.4-13.0 in. H_2O
Mist Elim. Pressure Drop = 0.45-0.48 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 47-58 wt %
Lime Addition to Downcomer

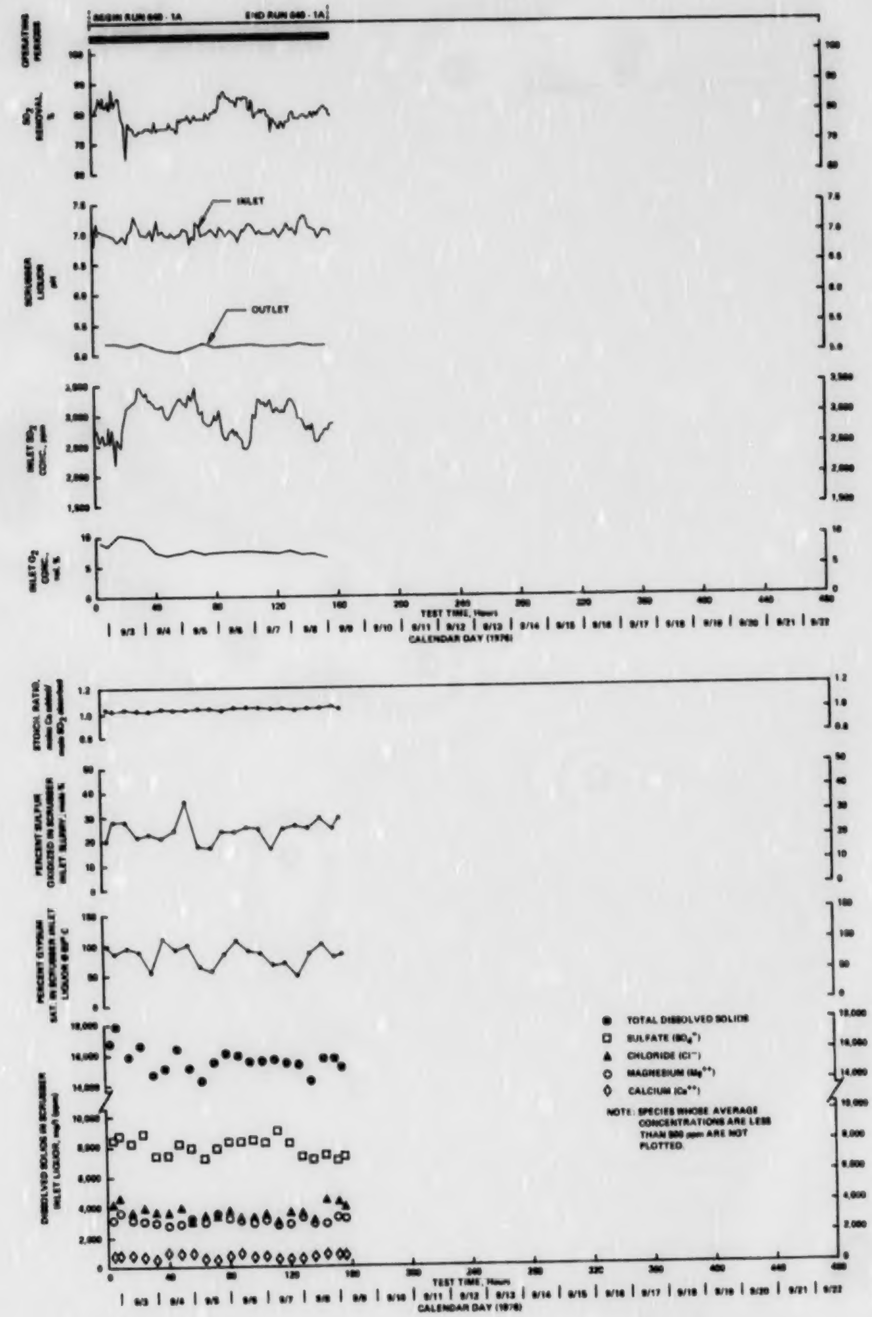
Figure F-11. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN 638 - 1A



Gas Rate = 35,000 acfm @ 330° F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 1,400 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time 3 min

Percent Solids Recirculated = 4-5 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 12.6-13.8 in. H_2O
Mist Elim. Pressure Drop = 0.47-0.60 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 44-54 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

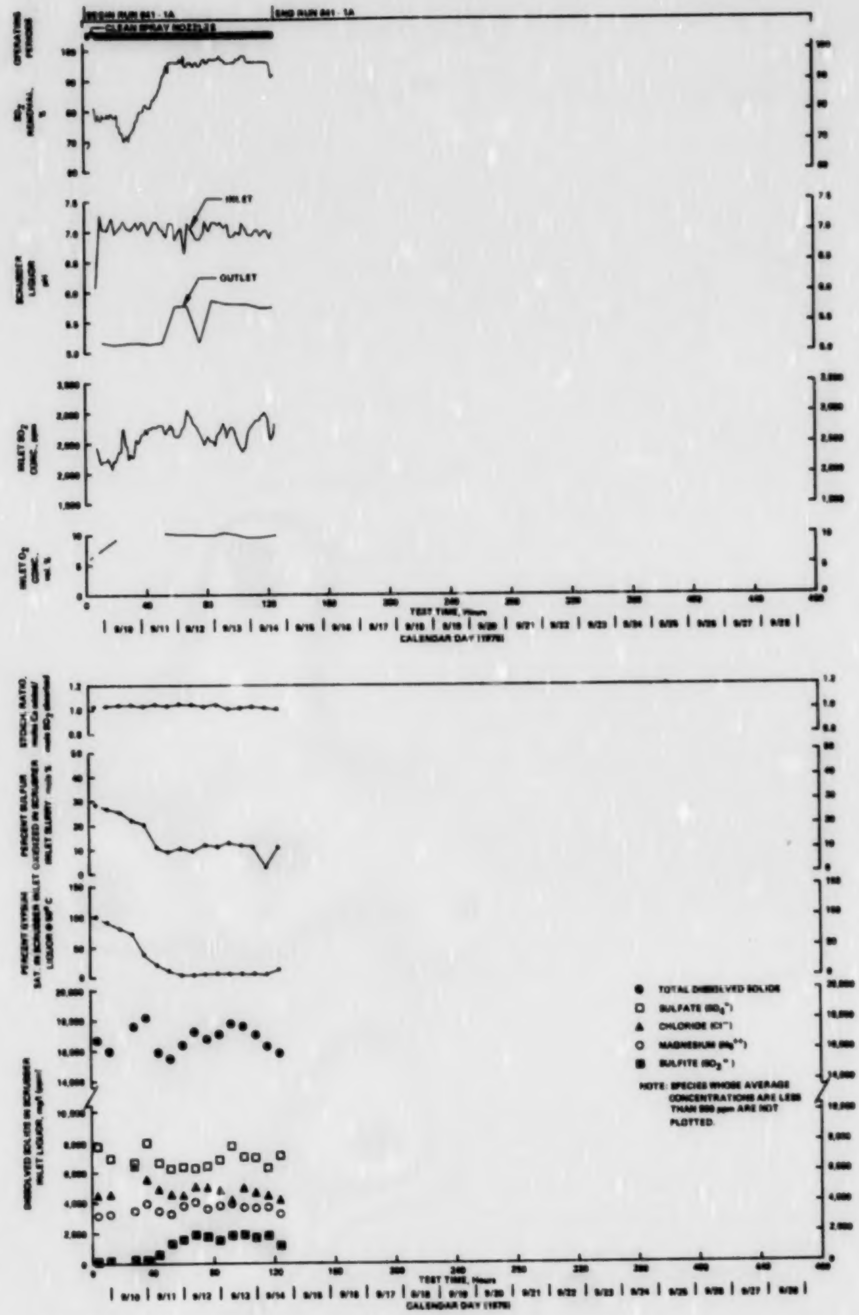
Figure F-12. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN 639 - 1A



Gas Rate = 35,000 acfm @ 330° F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 1,400 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 3 min

Percent Solids Recirculated = 7.7-8.8 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 13.2-13.8 in. H_2O
Mist Elim. Pressure Drop = 0.45-0.52 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 48-51 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

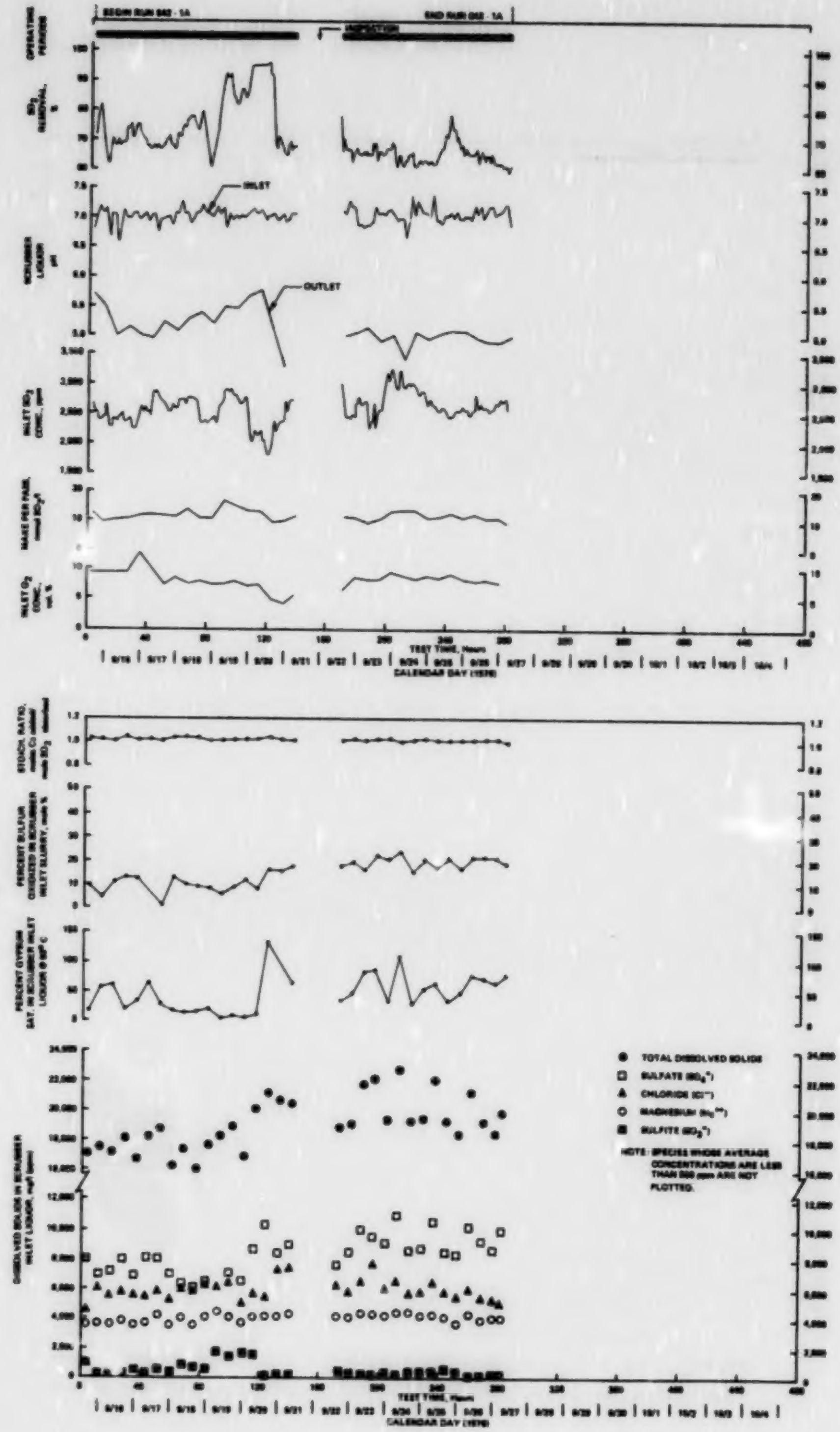
Figure F-13. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN 640 - 1A



Gas Rate = 35,000 acfm @ 330° F
Spray Tower Gas Velocity = 8.4 ft/sec
Liquor Rate to Venturi = 140 gpm
Liquor Rate to Spray Tower = 1,400 gpm
Venturi L/G = 5 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 3 min

Percent Solids Recirculated = 7.9-8.5 wt %
Venturi Pressure Drop = 3.4-3.7 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
=6.4-7.2 in. H_2O
Mist Elim. Pressure Drop = 0.48-0.51 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 45-50 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

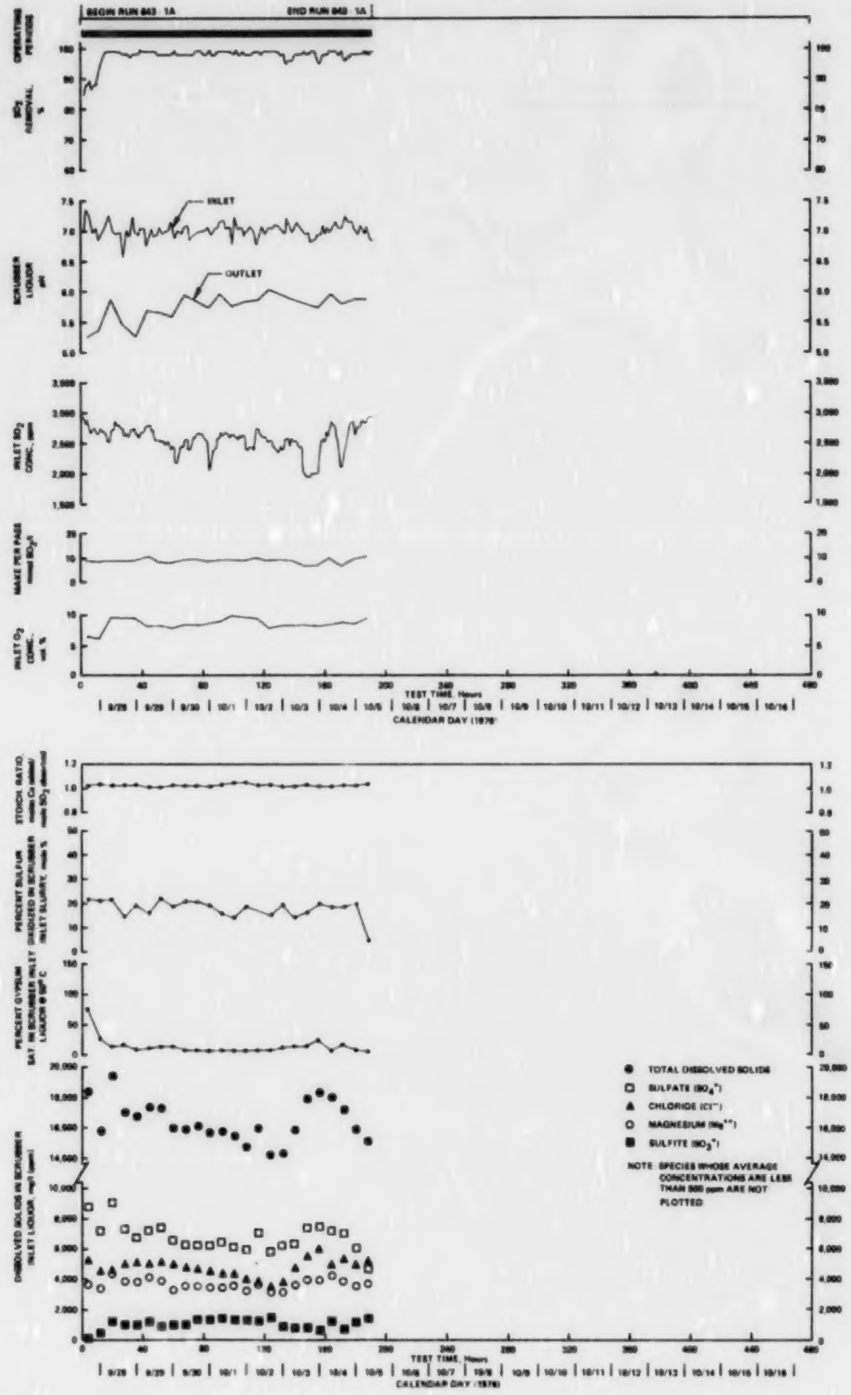
Figure F-14. OPERATING DATA FOR VENTURI/ SPRAY TOWER RUN 641 - 1A



Gas Rate = 35,000 acfm @ 330° F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 140 gpm
Liquor Rate to Spray Tower = 1,050 gpm
Venturi L/G = 5 gal/mcf
Spray Tower L/G = 37 gal/mcf
No. of Spray Headers = 3
EHT Residence Time = 3 min

Percent Solids Recirculated = 7.3-8.7 wt %
Venturi Pressure Drop = 3.0-4.1 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 6.5-7.5 in. H_2O
Mist Elim. Pressure Drop = 0.48-0.51 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 45-57 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

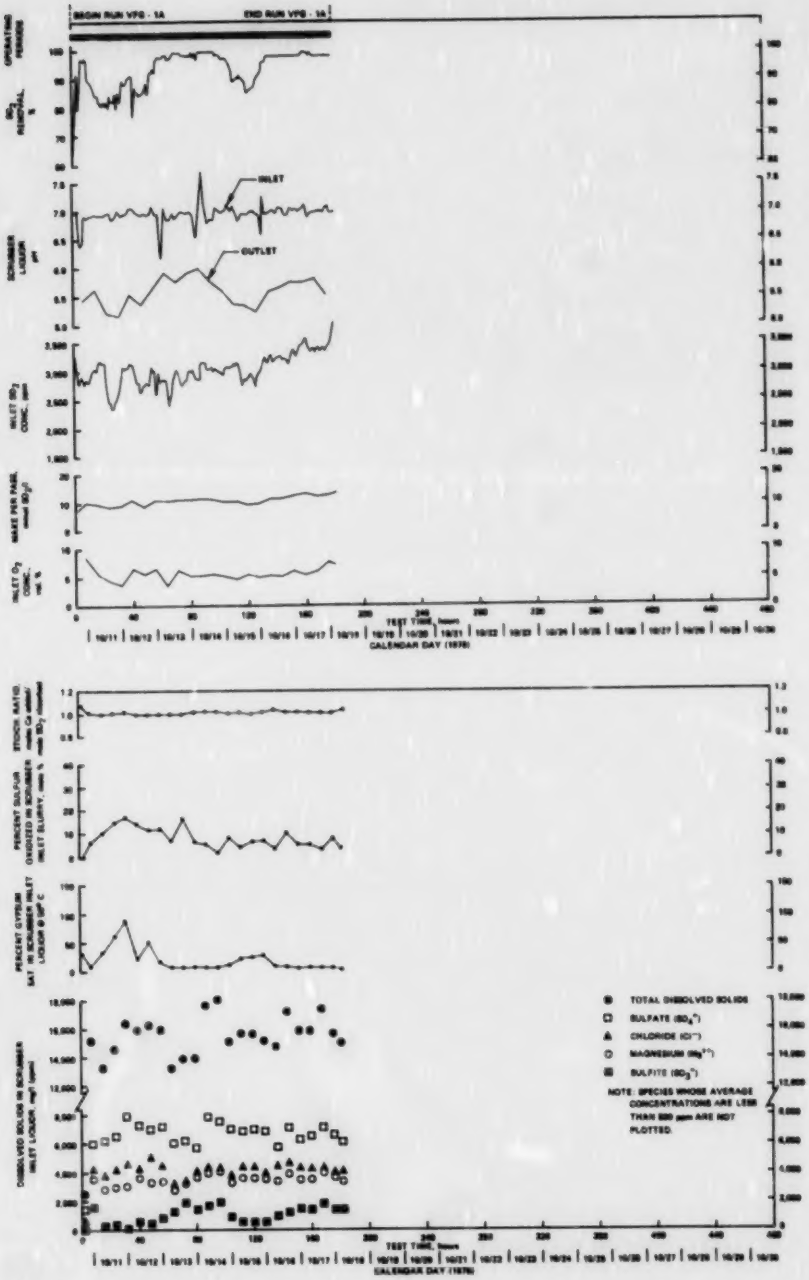
Figure F-15. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN 642 - 1A



Gas Rate = 35,000 acfm @ 330° F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 1,400 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 3 min

Percent Solids Recirculated = 7.6-8.6 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 12.7-13.3 in. H_2O
Mist Elim. Pressure Drop = 0.41-0.48 in. H_2O
Discharge (Clarifier & Centrifuge) Solids
Concentration = 41-46 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

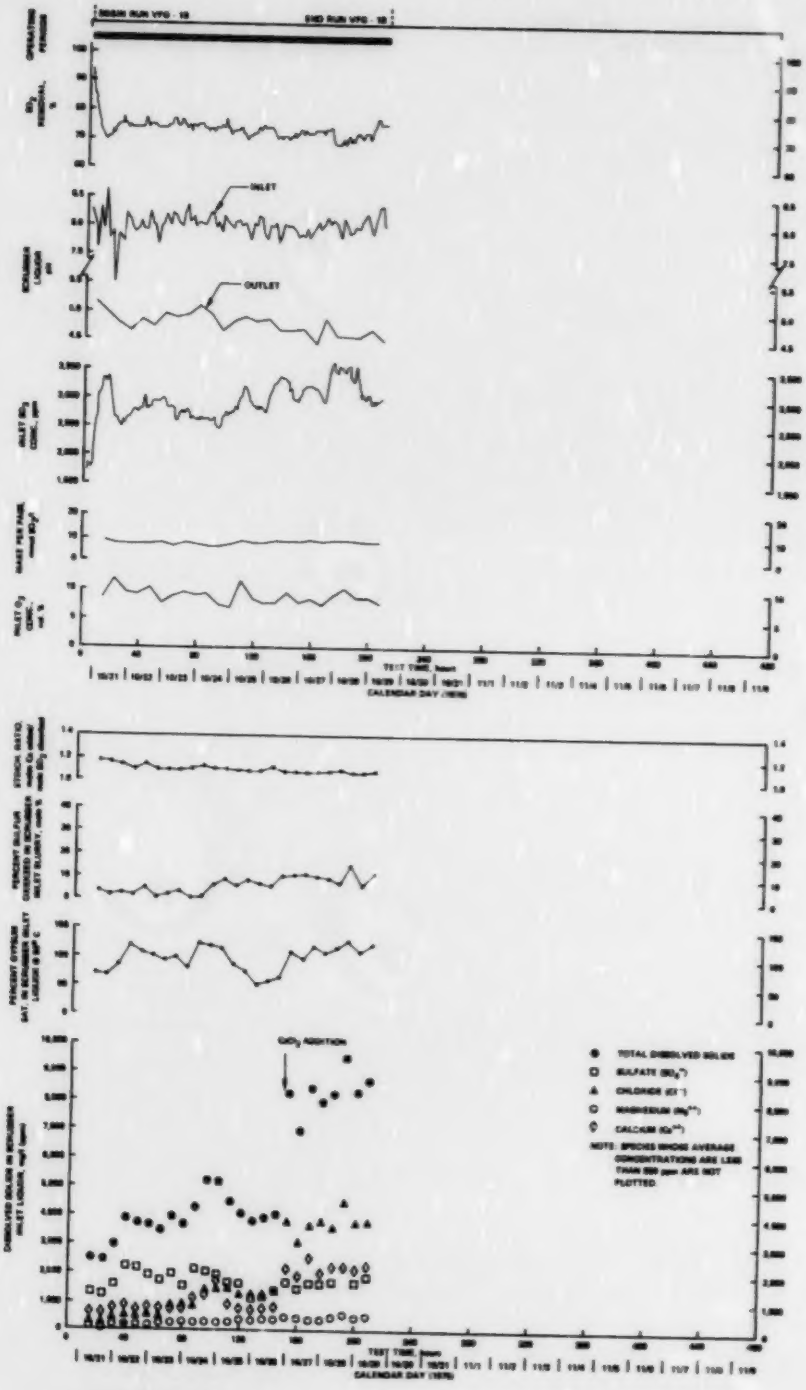
Figure F-16. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN 643 - 1A



Gas Rate = 35,000 acfm @ 330° F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 1400 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 3 min

Percent Solids Recirculated = 7.8-8.1 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 12.7-13.3 in. H_2O
Mist Elim. Pressure Drop = 0.44-0.48 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 48-57 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

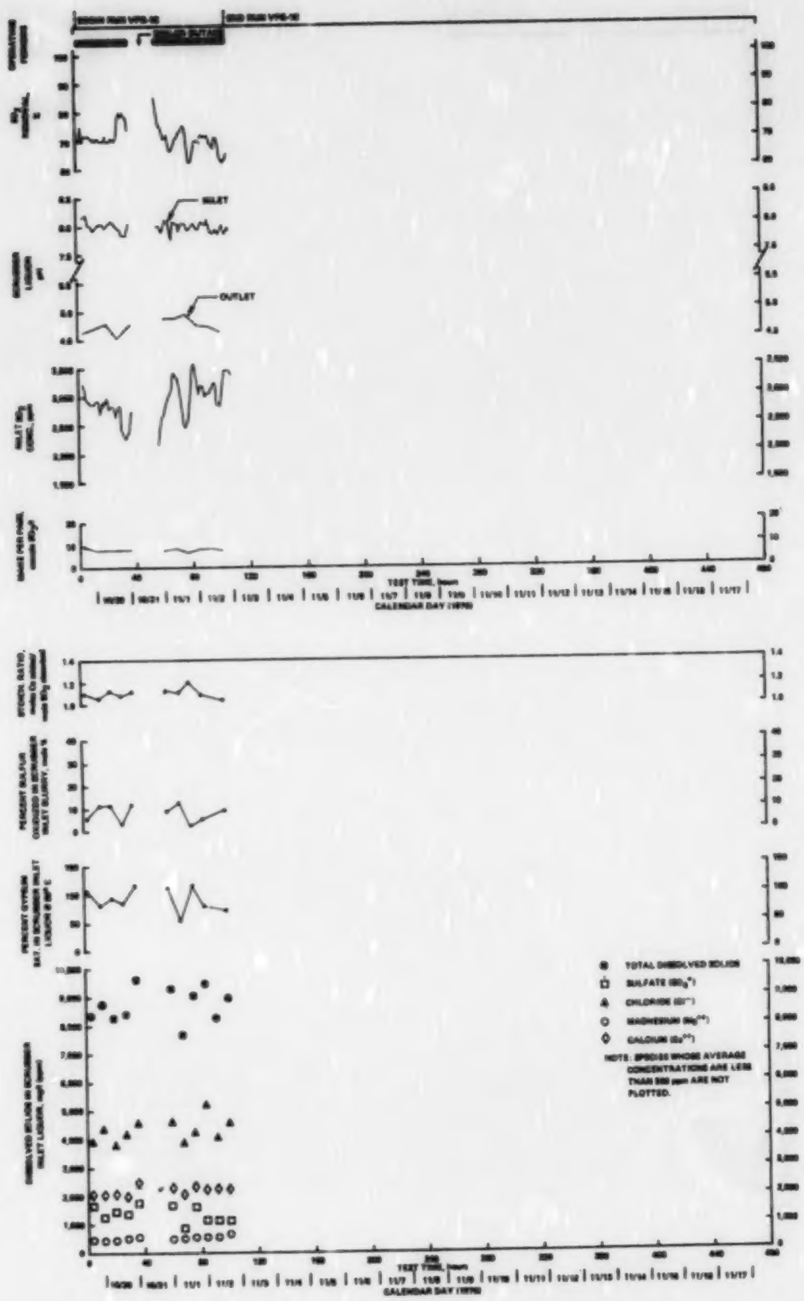
Figure F-17. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN VFG - 1A



Gas Rate = 35,000 acfm @ 330° F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 1400 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 12 min

Percent Solids Recirculated = 7.0-8.6 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 12.5-13.8 in. H_2O
Mist Elim. Pressure Drop = 0.45-0.50 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 42-62 wt %
Lime Addition to Downcomer

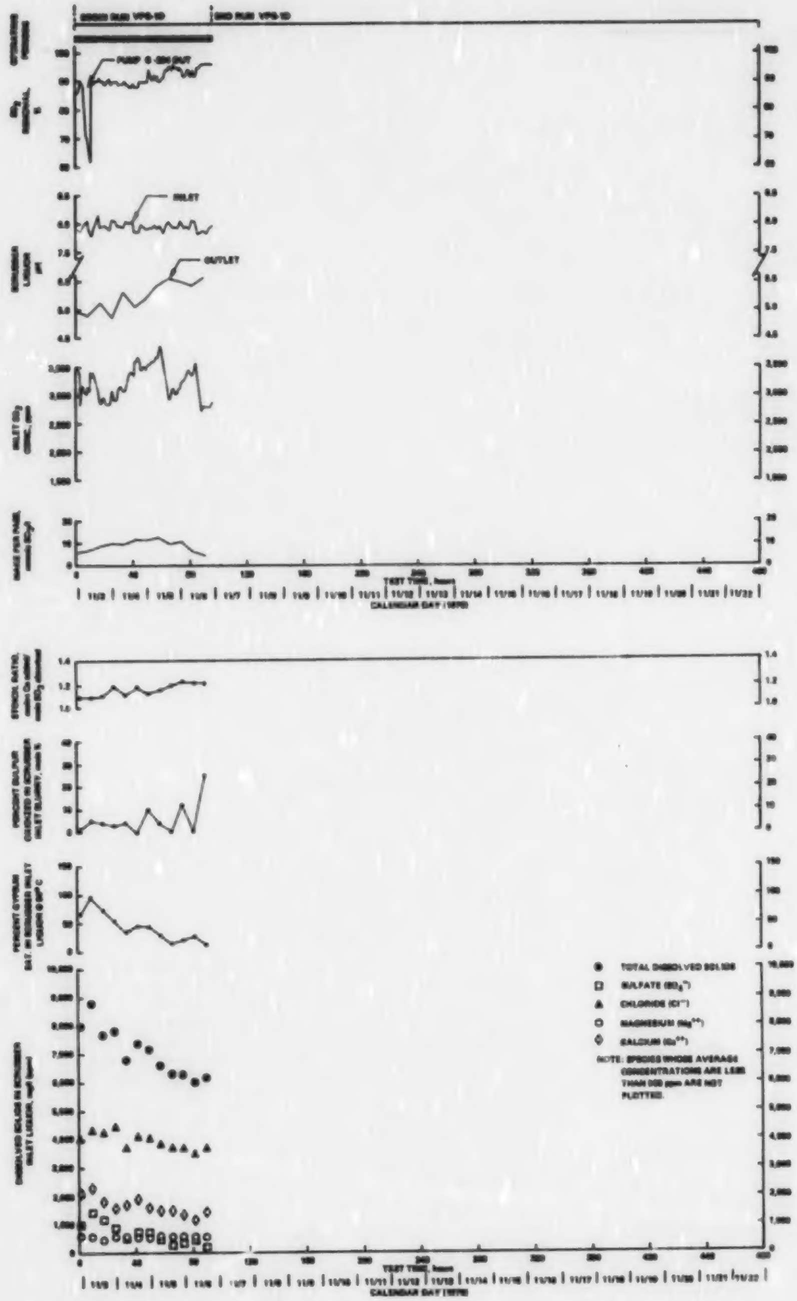
Figure F-1B. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN VFG - 1B



Gas Rate = 35,000 acfm @ 230° F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 900 gpm
Liquor Rate to Spray Tower = 1400 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 12 min

Percent Solids Recirculated = 8.1-8.3 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 12.8-13.9 in. H_2O
Mist Elim. Pressure Drop = 0.45-0.50 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 53-60 wt %
Lime Addition to Downcomer

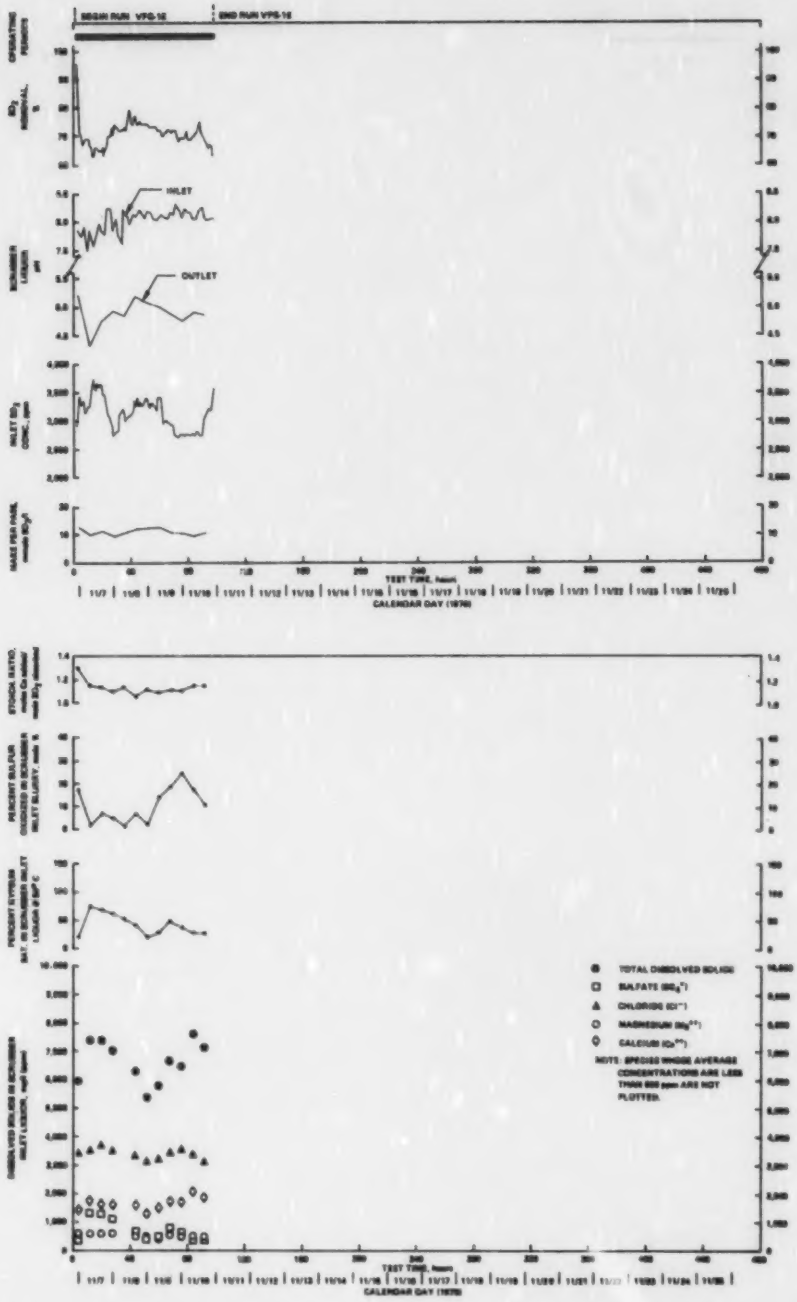
Figure F-19. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN VFG - 1C



Gas Rate = 20,000 acfm @ 330° F
Spray Tower Gas Velocity = 5.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 1400 gpm
Venturi L/G = 37 gal/mcf
Spray Tower L/G = 87 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 12 min

Percent Solids Recirculated = 7.8-8.4 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 10.1-10.7 in. H_2O
Mist Elim. Pressure Drop = 0.11-0.15 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 51-57 wt %
Lime Addition to Downcomer

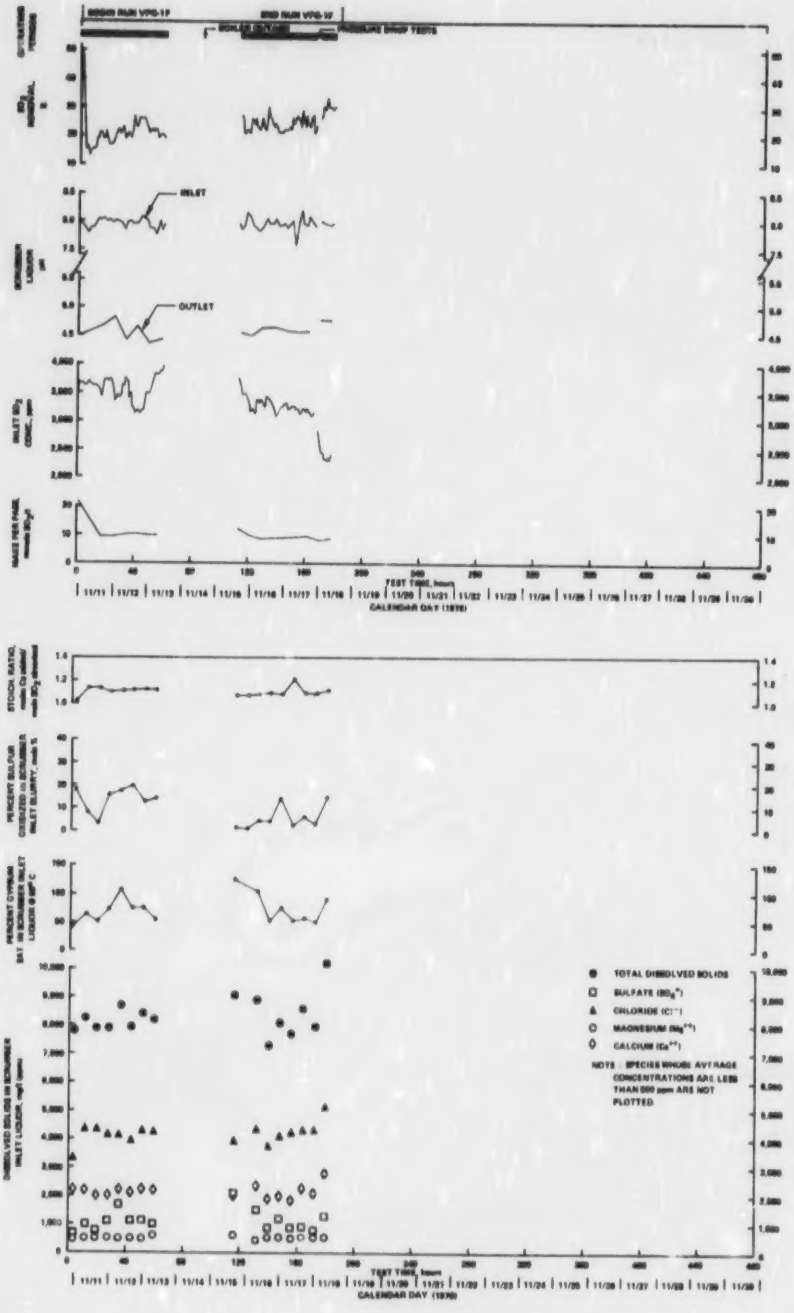
Figure F-20. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN VFG - 1D



Gas Rate = 35,000 acfm @ 330° F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 375 gpm
Liquor Rate to Spray Tower = 1400 gpm
Venturi L/G = 13 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 12 min

Percent Solids Recirculated = 7.0-8.9 wt %
Venturi Pressure Drop = 4.1-[illegible] in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 9.3-10.8 in. H_2O
Mist Elim. Pressure Drop = 0.43-0.58 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 45-83 wt %
Lime Addition to Downcomer

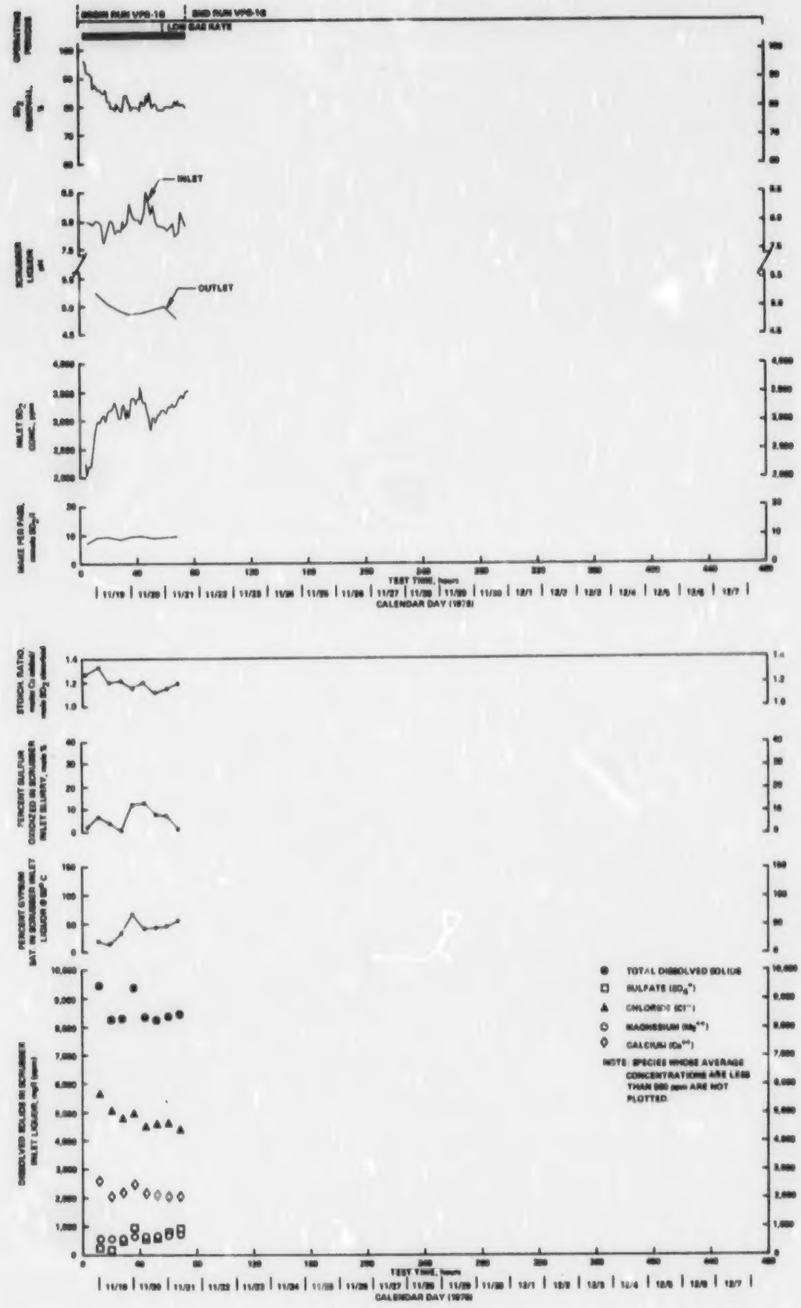
Figure F-21. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN VFG - 1E



Gas Rate = 35,000 acfm @ 330° F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 0 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 0 gal/mcf
No. of Spray Headers = 0
EHT Residence Time = 20 min

Percent Solids Recirculated = 7.8-9.0 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 11.5-13.5 in. H_2O
Mist Elim. Pressure Drop = 0.37-0.45 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 58-64 wt %
Lime Addition to Downcomer

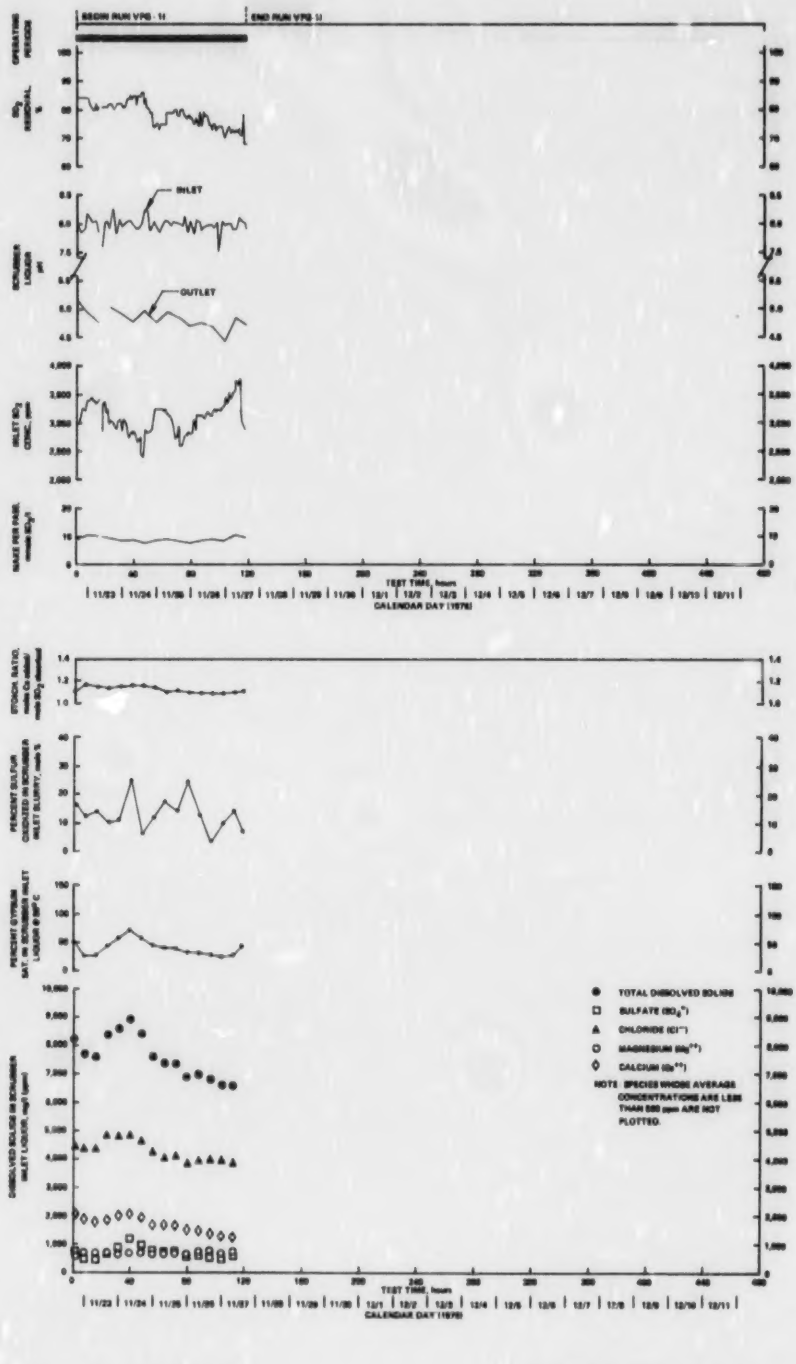
Figure F-22. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN VFG - 1F



Gas Rate = 35,000 acfm @ 330° F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 1400 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 12 min

Percent Solids Recirculated = 7.2-8.8 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 13.4-13.8 in. H_2O
Mist Elim. Pressure Drop = 0.75-1.75 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 51-54 wt %
Lime Addition to Downcomer

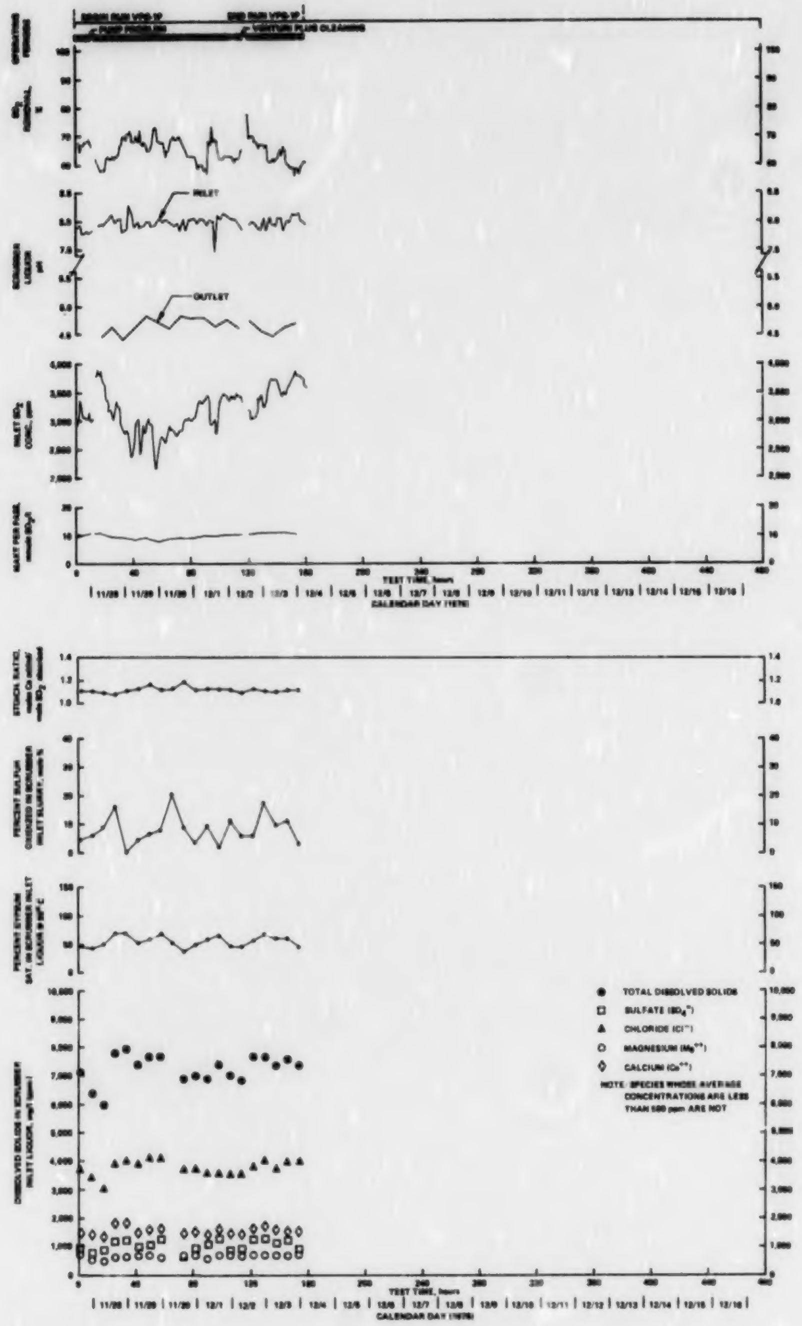
Figure F-23. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN VFG - 1G



Gas Rate = 35,000 acfm @ 330° F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 600 gpm
Liquor Rate to Spray Tower = 1400 gpm
Venturi L/G = 21 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 12 min.

Percent Solids Recirculated = 14.6-15.9 wt %
Venturi Pressure Drop = 9 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 13.1-13.8 in. H_2O
Mist Elim. Pressure Drop = 0.37-0.44 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 52-56 wt %
Lime Addition to Downcomer

Figure F-24. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN VFG - 1I



Gas Rate = 35,000 acfm @ 330° F
Spray Tower Gas Velocity = 9.4 ft/sec
Liquor Rate to Venturi = 140 gpm
Liquor Rate to Spray Tower = 1400 gpm
Venturi L/G = 5 gal/mcf
Spray Tower L/G = 50 gal/mcf
No. of Spray Headers = 4
EHT Residence Time = 12 min

Percent Solids Recirculated = 7.5-9.1 wt %
Venturi Pressure Drop = 1.4-5.7 in. H_2O
Total Pressure Drop, Excluding Mist Elim.
= 5.7-9.3 in. H_2O
Mist Elim. Pressure Drop = 0.35-0.42 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 55-60 wt %
Lime Addition to Downcomer

Figure F-25. OPERATING DATA FOR VENTURI/SPRAY TOWER RUN VFG - 1P

APPENDIX G

AVERAGE LIQUOR COMPOSITIONS FOR THE VENTURI/SPRAY TOWER TESTS

Table G-1

AVERAGE SCRUBBER INLET LIQUOR COMPOSITIONS FOR LIME/MgO TESTS AND A FLY ASH-FREE LIMESTONE TEST (718-1A)

Run No.	Percent Solids Discharged	Percent Sulfur Oxidized	pH	Liquor Species Concentrations, mg/l (ppm)								Calculated Percent Sulfate Saturation at 50°C [(a)]
				Ca^{++}	Mg^{++}	Na^+	K^+	$SO_3^=$	$SO_4^=$	Cl^-	Total	
629-1A	56	20	6.00	610	3770	50	100	890	9890	3880	19200	75
630-1A	53	15	7.10	245	3920	65	100	770	7680	5570	18400	25
631-1A	56	17	7.00	585	4560	50	80	480	8100	7430	21300	50
632-1A	54	18	7.00	230	4600	55	90	780	7250	7100	20200	20
633-1A	51	15	7.05	170	4000	40	95	1110	8100	5000	18600	15
634-1A	58	11	8.00	2050	370	15	15	70	1440	3630	7600	100
635-1A	47	20	8.00	2300	640	20	20	100	1530	4600	9250	95
636-1A	44	16	8.00	2200	650	20	20	75	1430	4300	8750	85
637-1A	47	15	7.90	1600	600	15	17	92	1455	3330	7120	80
638-1A	53	17	8.00	2100	625	11	24	110	2050	3690	8620	120
639-1A	49	28	7.00	840	3230	8	15	270	8840	3420	16620	105
640-1A	50	24	7.05	730	3130	11	15	180	7900	3650	15600	85
641-1A	48	11	7.00	80	3710	9	15	1650	6750	4560	16800	6
642-1A	51	14	6.95	460	3990	11	16	420	8320	5740	18950	45
643-1A	43	18	6.95	115	3710	12	16	1110	6720	4690	16370	9
718-1A	55	22	5.90	2350	600	20	17	110	1880	4500	9550	120

Note: The values in this table are averages for the steady-state operating periods.

(a) (activity Ca^{++}) x (activity $SO_4^=$) / (solubility product at 50°C). Estimated solubility product for $CaSO_4 \cdot 2H_2O$ at 50°C is 2.2×10^{-5} (ref. Radian Corporation "A Theoretical Description of the Limestone-Injection Wet Scrubbing Process", NAPCA Report, June 9, 1970).

Table G-2

AVERAGE SCRUBBER INLET LIQUOR COMPOSITIONS FOR FLUE GAS CHARACTERIZATION TESTS

Run No.	Percent Solids Discharged	Percent Solids Oxidized	pH	Liquor Species Concentrations, mg/l (ppm)								Calculated Percent Sulfate Saturation @ 50°C[(a)]
				Ca^{++}	Mg^{++}	Na^+	K^+	$SO_3^=$	$SO_4^=$	Cl^-	Total	
VFG-1A	52	9	6.95	205	3470	37	41	1040	6750	4140	15700	20
VFG-1B	52	9	7.95	2200	490	12	67	47	1750	3790	8350	115
VFG-1C	57	7	8.00	2220	565	21	77	105	1420	4330	8730	90
VFG-1D	54	6	7.95	1680	570	43	89	59	720	3920	7090	40
VFG-1E	54	11	8.05	1660	530	37	100	77	760	3550	6710	45
VFG-1F	62	11	7.95	2190	540	59	115	72	1170	4290	8440	75
VFG-1G	53	7	8.00	2200	640	62	114	113	630	4760	8520	40
VFG-1I	54	15	8.00	1710	700	59	116	52	720	4250	7610	40
VFG-1P	58	10	7.95	1590	720	50	95	65	1120	3790	7440	55

Note: The values in this table are averages for the steady-state operating periods.

(a) (activity Ca^{++}) x (activity $SO_4^=$)/(solubility product at 50°C). Estimated solubility product for $CaSO_4 \cdot 2H_2O$ at 50°C is 2.2×10^{-5} (ref. Radian Corporation, "A Theoretical Description of the Limestone-Injection Wet Scrubbing Process", NAPCA Report, June 9, 1970).

APPENDIX H

TEST RESULTS SUMMARY TABLES FOR THE TCA

Table H-1

SUMMARY OF LIMESTONE/MGO TESTS ON THE TCA SYSTEM

Run Number	583-2A	583-2B	584-2A	585-2A
Start-of-Run Date	4/15/76	4/21/76	5/3/76	5/14/76
End-of-Run Date	4/21/76	5/1/76	5/14/76	5/20/76
On Stream Hours	131	230	236	140
Gas Rate, acfm @ 300°F	30,000	30,000	30,000	30,000
Gas Velocity, fps @ 125°F	12.5	12.5	12.5	12.5
Liquor Rate, gpm	1200	1200	1200	900
L/G, gal/mcf	50	50	50	37
Percent Solids Recirculated	13.2-16.4	13.0-17.6	14-18	13-16
Effluent Residence Time, min.	3.0	3.0	3.0 (5/3-5/6)/4.1 (5/7-5/14)	4.1
Stoichiometric Ratio, moles Ca added/mole SO_2 absorbed	1.1-1.4	1.1-1.5[a]	1.1-1.5[b]	1.1-1.4[c]
Avg. % Limestone Utilization, 100x moles SO_2 abs./mole Ca added	80	77[a]	77[b]	77[c]
Inlet SO_2 Concentration, ppm	2300-3800	2300-3500	2200-3700	2200-3600
Percent SO_2 Removal	67-86	72-96	90-98	77-93
Scrubber Inlet pH Range	5.2-5.7	5.0-5.6	5.1-5.7	5.2-5.6
Scrubber Outlet pH Range	5.0-5.2	4.9-5.2	4.9-5.5	4.9-5.2
Percent Sulfur Oxidized	20-48	15-45	10-30	15-40
Solids Disposal System	Clarifier	Centrifuge	Clarifier/Centrifuge	Clarifier
Loop Closure, % Solids Dischg.	33-41	55-64	32-38 (Clar.)/53-61 (Cent.)	33-36
Calculated Avg % Sulfate Saturation in Scrubber Inlet Liquor @ 50°C	145	110	50	105
Total Dissolved Solids, ppm	14,000 - 19,000	28,000-40 000	38,000-66,000	44,000-60,000
Total ΔP Range Excluding Mist Elimination System, in. H_2O	7.5-11.2	8.7-14.9	7.5-10.5	7.0-8.6
Mist Elimination System ΔP Range, in. H_2O	0.45-0.53	0.45-0.53	0.45-0.55	0.53-0.58
Mist Elimination System Configuration	3-pass, open-vane, 316 SS chevron mist eliminator.	3-pass, open-vane, 316 SS chevron mist eliminator.	3-pass, open-vane, 316 SS chevron mist eliminator.	3-pass, open-vane, 316 SS chevron mist eliminator.
Absorbent	Limestone slurried to 60 wt % with makeup water and added added to EHT.	Limestone slurried to 60 wt % with makeup water and added to EHT plus MgO dry fed to EHT.	Limestone slurried to 60 wt % with makeup water and added to downcomer. MgO dry fed to EHT.	Limestone slurried to 60 wt % with makeup water and added to downcomer. MgO dry fed to EHT.
Mist Eliminator Washing Scheme	Top washed sequentially with makeup water. Each nozzle (6 total) on 3 minutes (at 0.55 gpm/ft²), with 7 minutes off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/ft², for 4 minutes/hour.	Top washed sequentially with makeup water. Each nozzle (6 total) on 3 minutes (at 0.55 gpm/ft²), with 7 minutes off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/ft², for 4 minutes/hour.	Top washed sequentially with makeup water. Each nozzle (6 total) on 3 minutes (at 0.55 gpm/ft²) with 7 minutes off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/ft² for 4 minutes/hour.	Top washed sequentially with makeup water. Each nozzle [illegible]otal) on 3 minutes (at 0.55 gpm/ft²) with 7 minutes off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/ft² for 4 minutes/hour.
Scrubber Internals	3 beds (4 grids) with 5 inches spheres/stage. All beds worn nitrile foam spheres from previous run.	3 beds (4 grids) with 5 inches spheres/stage. All beds worn nitrile foam spheres from previous run.	3 beds (4 grids) with 5 inches spheres/stage. All beds worn nitrile foam spheres from previous run.	3 beds (4 grids) with 5 inches spheres/stage. All beds worn nitrile foam spheres from previous run.
System Changes Before Start of Run	System cleaned.	No cleaning. No changes.	No changes. No cleaning.	No changes. No cleaning.
Method of Control	Stoichiometric ratio controlled at 1.2 moles Ca/mole SO_2 absorbed.	Stoichiometric ratio controlled at 1.2 moles Ca/mole SO_2 absorbed, plus Mg ion conc. in liquor controlled at $(5000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.	Stoichiometric ratio controlled at 1.2 moles Ca/mole SO_2 absorbed. Mg ion conc. in liquor controlled at $(9000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.	Stoichiometric ratio controlled at 1.2 moles Ca/mole SO_2 absorbed. Mg ion conc. in liquor controlled at $(9000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.
Run Philosophy	Run made without MgO addition for comparison with 583-2B, with MgO addition.	MgO addition test with one tank at a 1.0 minutes residence time.	To obtain sulfate unsaturated operation at a higher Mg ion concentration in the liquor.	Run made to determine liquor rate effect (Run 585-2A vs Run 584-2A).
Results	Mist Eliminator 2% restricted at end of run. Run provides a comparison with following run.	Mist eliminator slightly cleaner at end of run (1% vs 2% at start). Expected sulfate unsaturation not achieved, however, good SO_2 removal (avg 84%) was achieved. [a] Total stoich. ratio for Ca & Mg is 1.15-1.55 (avg. alkali util. = 74%).	Unsaturated sulfate operation was maintained during run. Mist eliminator restriction increased from 1 to 4 percent. Heavy solids buildup on duct wall opposite Bloom reheater discharge. [b] Total stoich. ratio for Ca & Mg is 1.2-1.6 (avg. alkali util. = 71%).	Percent sulfate saturation was 105%. Mist eliminator remained 4% restricted. [c] Total stoich. ratio for Ca & Mg is 1.3-1.6 (avg. alkali util. = 69%).

Table H-1 (continued)

SUMMARY OF LIMESTONE/MGO TESTS ON THE TCA SYSTEM

Run No.	586-2A	587-2A	588-2A	589-2A
Start-of-Run Date	5/20/76	5/31/76	6/16/76	6/21/76
End-of-Run Date	5/25/76	6/14/76	6/21/76	7/1/76
On Stream Hours	110	295	107	200
Gas Rate, acfm @ 300°F	30,000	30,000	20,500	30,000
Gas Velocity, fps @ 125°F	12.5	12.5	8.6	12.5
Liquor Rate, gpm	1200	1200	1200	1200
L/G, gal/mcf	50	50	73	50
Percent Solids Recirculated	14-16	8-11	13-15	14-16
Effluent Residence Time, min	4.1	4.1	4.1	4.1
Stoichiometric Ratio, moles Ca added/mile SO_2 absorbed	1.1-1.3$^{(a)}$	1.15-1.55$^{(b)}$	1.6-2.2$^{(c)}$	1.05-1.45$^{(d)}$
Avg. % Limestone Utilization, 100x moles SO_2 abs./mole Ca added	83$^{(a)}$	74$^{(b)}$	53$^{(c)}$	80$^{(d)}$
Inlet SO_2 Concentration, ppm	2200-3300	2600-3600	1800-3300	3000-4200
Percent SO_2 Removal	72-88	88-98	90-97	86-94
Scrubber Inlet pH Range	5.1-5.5	5.1-5.5	5.1-5.6	5.3-5.6
Scrubber Outlet pH Range	4.95-5.15	4.8-5.1	4.9-5.4	4.9-5.2
Percent Sulfur Oxidized	10-35	15-40	22-40	8-22
Solids Disposal System	Clarifier	Clarif. & Cent. in Parallel	Centrifuge	Centrifuge
Loop Closure, % Solids Dischg.	36-37	30-55	60-68	52-61
Calculated Avg % Sulfate Saturation in Scrubber Inlet Liquor @ 50°C	70	125	125	120
Total Dissolved Solids, ppm	40,000-58,000	44,000-56,000	47,000-60,000	44,000-56,000
Total ΔP Range Excluding Mist Elimination System, in. H_2O	3.3-3.7	8.1-12.5	5.0-5.7	7.7-9.9
Mist Elimination System ΔP Range, in. H_2O	0.52-0.60	0.45-0.52	0.18-0.25	0.45-0.52
Mist Elimination System Configuration	3-pass, open-vane, 316 SS chevron mist eliminator.	3-pass, open-vane, 316 SS chevron mist eliminator.	3-pass, open-vane, 316 SS chevron mist eliminator.	3-pass, open-vane, 316 SS chevron mist eliminator.
Absorbent	Limestone slurried to 60 wt % with makeup water and added to downcomer. MgO dry fed to EHT.	Limestone slurried to 60 wt % with makeup water and added to downcomer. MgO dry fed to EHT.	Limestone slurried to 60 wt % with makeup water and added to downcomer. MgO dry fed to EHT.	Limestone slurried to 60 wt % with makeup water and added to downcomer. MgO dry fed to EHT.
Mist Eliminator Washing Scheme	Top washed sequentially with makeup water. Each nozzle (6 total) on 3 minutes (at 0.55 gpm/ft^2) with 7 minutes off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/ft^2 for 4 minutes/hour.	Top washed sequentially with makeup water. Each nozzle (6 total) on 3 minutes (at 0.55 gpm/ft^2) with 7 minutes off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/ft^2 for 4 minutes/hour.	Top washed sequentially with makeup water. Each nozzle (6 total) on 3 minutes (at 0.55 gpm/ft^2) with 7 minutes off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/ft^2 for 4 minutes/hour.	Top washed sequentially with makeup water. Each nozzle (6 total) on 3 minutes (at 0.55 gpm/ft^2) with 7 minutes off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/ft^2 for 4 minutes/hour.
Scrubber Internals	Four support grids, no spheres.	Three beds (4 grids) with 5 inches spheres/bed. All worn nitrile foam spheres from Run 585-2A.	Three beds (4 grids) with 5 inches spheres/bed. Bottom bed with worn nitrile foam spheres from Run 587-2A. Top & middle beds with new nitrile foam spheres.	Three beds (4 grids) with 5 inches spheres/bed. All worn nitrile foam spheres from Run 588-2A.
System Changes Before Start of Run	All spheres removed. No cleaning.	No cleaning. Reinstalled three 5-inch beds of spheres used in Run 585-2A.	Replaced top and middle bed spheres with new ones. No cleaning.	No changes. No cleaning.
Method of Control	Stoichiometric ratio controlled at 1.2 moles Ca/mole SO_2 absorbed. Mg ion conc. in liquor controlled at $(9000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm	Stoichiometric ratio controlled at 1.2 moles Ca/mole SO_2 absorbed. Mg ion conc. in liquor controlled at $(9000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm	Stoichiometric ratio controlled at 1.2 moles Ca/mole SO_2 absorbed. Mg ion conc. in liquor controlled at $(9000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm	Scrubber inlet liquor pH controlled at 5.4 ± .1. Override: Stoich. Ratio 1.8. Mg ion conc. in liquor controlled at $(9000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm
Run Philosophy	To observe effect of removing the spheres on SO_2 removal and sulfate saturation. (Direct comparison with Run 584-2A).	To observe the effect of lower percent solids in the recirculating slurry on the sulfate saturation (cf. Run 584-2A).	To observe the effect of high L/G (lower gas rate) on sulfate saturation (cf. Run 584-2A).	To determine if wide fluctuations in percent SO_2 removal as seen in Run 584-2A can be minimized at a controlled pH of 5.4.
Results	Average percent SO_2 removal was 80%, compared with 94% in 584-2A. Average sulfate saturation was 70% compared with 50% for 584-2A. Mist eliminator restriction increased to 5% from previous run. (a) Total stoich. ratio for Ca & Mg is 1.3-1.5 (avg. alkali util. = 71%).	Sulfate saturation increased from 50% (584-2A) to 125% this run. Scale build-up on walls below bottom grid. Mist eliminator restriction decreased from 5 to 2 percent during run. (b) Total stoich. ratio for Ca & Mg is 1.26-1.70 (avg. alkali util. = 68%).	Sulfate saturation increased from 50% (584-2A) to 125% this run. SO_2 removal unchanged at avg. 94%, but limestone utilization dropped to 53% this run (cf 77% in 584-2A). (c) Total stoich. ratio for Ca & Mg is 1.68-2.30 (avg. alkali util. = 50%).	Range of SO_2 removals was 86 to 94 percent (cf 90 to 98 percent in 584-2A) while inlet pH ranged over 0.3 units (5.3 to 5.6), compared with 0.6 units (5.1 to 5.7) in 584-2A. Scale build-up on walls below bottom grid continued. (d) Total stoich. ratio for Ca & Mg is 1.12-1.54 (avg. alkali util. = 75%).

Table H-2

SUMMARY OF LIME TESTS ON THE TCA SYSTEM

Run Number	601-2A	602-2A	603-2A	604-2A
Start-of-Run Date	7/1/76	7/12/76	7/19/76	7/28/76
End-of-Run Date	7/12/76	7/18/76	7/26/76	8/4/76
On Stream Hours	177	137	165	158
Gas Rate, acfm @ 300°F	30,000	30,000	30,000	30,000
Gas Velocity, fps @ 125°F	12.5	12.5	12.5	12.5
Liquor Rate, gpm	1200	1200	1200	900
L/G, gal/mcf	50	50	50	37
Percent Solids Recirculated	8-9	14-16	7-9	7-8
Effluent Residence Time, min	4.1	4.1	4.1	4.1
Stoichiometric Ratio, moles Ca added/mole SO_2 absorbed	1.00-1.08[a]	1.00-1.05[b]	0.98-1.02[c]	0.99-1.02[d]
Avg. % Lime Utilization, 100x moles SO_2 abs./mole Ca added	96[a]	98[b]	100[c]	100[d]
Inlet SO_2 Concentration, ppm	2600-3200	2600-3700	2200-4500	2800-3600
Percent SO_2 Removal	88-96	85-91	75-92	68-78
Scrubber Inlet pH Range	6.8-7.6	6.6-7.4	6.7-7.2	6.7-7.1
Scrubber Outlet pH Range	5.0-5.4	4.9-5.3	4.9-5.3	4.8-5.0
Inlet O_2 Concentration, vol. %	5.0-7.0	4.5-7.0	5.0-7.5	5.0-7.0
Percent Sulfur Oxidized	10-18	5-23	15-25	22-35
Solids Disposal System	Clarifier & Centrifuge	Clarifier & Centrifuge	Clarifier & Centrifuge	Clarifier & Centrifuge
Loop Closure, % Solids Dischg.	54-60	57-60	58-63	58-62
Calculated Avg % Sulfate Saturation in Scrubber Inlet Liquor @ 50°C	50	40	75	90
Total Dissolved Solids, ppm	12,400-15,600	12,000-15,400	14,400-17,600	14,400-17,200
Total Δ P Range Excluding Mist Elimination System, in. H_2O	7.9-9.5	7.9-8.7	7.5-9.1	6.6-7.9
Mist Elimination System ΔP Range, in. H_2O	0.47-0.52	0.49-0.51	0.49-0.53	0.52-0.88
Mist Elimination System Configuration	3-pass, open-vane, 316L SS, chevron mist eliminator	3-pass, open-vane, 316L SS, chevron mist eliminator	3-pass, open-vane, 316L SS, chevron mist eliminator	3-pass, open-vane, 316L SS, chevron mist eliminator
Absorbent	Lime slurried to 20 wt. % with makeup water and added to downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt. % with makeup water and added to downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt. % with makeup water and added to EHT. MgO dry fed to EHT.	Lime slurried to 20 wt. % with makeup water and added to downcomer. MgO dry fed to EHT.
Mist Eliminator Washing Scheme	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.
Scrubber Internals	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from Run 589-2A. Estimated total actual bed height was 14.5 in.	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run. Estimated total actual bed height was 14.5 in.	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run. Estimated total actual bed height was 14.5 in.	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run. Estimated total actual bed height was 14.0 in.
System Changes Before Start of Run	No changes. Clarifier dumped and cleaned.	No changes. No cleaning.	No changes. No cleaning.	No changes. No cleaning.
Method of Control	Scrubber inlet liquor pH controlled at 7.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.	Scrubber inlet liquor pH controlled at 7.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.	Scrubber inlet liquor pH controlled at 7.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.	Scrubber inlet liquor pH controlled at 7.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.
Run Philosophy	First run (base case) of a series of lime tests with and without MgO addition. Run conditions selected to obtain good SO_2 removal and sulfate (gypsum) unsaturated operation.	To observe the effect of higher percent solids recirculated (maintained at approx. 15% cf. 8% during Run 601-2A). Other operating conditions same as for Run 601-2A.	To observe the effect of lime addition to EHT (cf. lime addition to downcomer during 601-2A) on sulfate saturation. All other operating conditions same as for Run 601-2A.	To observe the effect of lower slurry rate (900 gpm cf. 1200 gpm for Run 601-2A) on SO_2 removal and sulfate saturation. All other conditions same as for Run 601-2A.
Results	SO_2 removal averaged 92% and lime utilization 96%. Average sulfate saturation was 50%. Mist eliminator was less than 1% restricted at end of run. [a] Total stoich. ratio for Ca & Mg is 1.02-1.10 (avg. alkali util. = 94%).	Results not significantly changed from Run 601-2A. SO_2 removal averaged 88%, lime utilization 98%, and sulfate saturation 40% (cf. 92, 96 and 50%, respectively, for 601-2A). Mist eliminator less than 1% restricted at end of run. [b] Total stoich. ratio for Ca & Mg is 1.02-1.07 (avg. alkali util. = 96%).	Sulfate saturation averaged 75% compared with 50% for Run 601-2A. Mist eliminator 3-5% restricted at end of run. [c] Total stoich. ratio for Ca & Mg is 1.00-1.04 (avg. alkali util. = 98%).	SO_2 removal averaged 73% (cf. 92% for 601-2A), and lime utilization averaged 100% (cf. 96% for 601-2A). Sulfate saturation was 90% (cf. 50% for 601-2A). The mist eliminator was 40% restricted at end of run. Heavy gypsum scaling occurred on the scrubber walls, bar grids, and outlet duct to reheater. [d] Total stoich. ratio for Ca & Mg is 1.01 - 1.04 (avg. alkali util. = 98%).

Table H-2 (continued)

SUMMARY OF LIME TESTS ON THE TCA SYSTEM

Run Number	605-2A	606-2A	607-2A	608-2A
Start-of-Run Date	8/5/76	8/13/76	8/19/76	9/3/76
End-of-Run Date	8/13/76	8/18/76	9/2/76	9/6/76
On Stream Hours	170	122	212	84
Gas Rate, acfm @ 300°F	20,500	30,000	30,000	30,000
Gas Velocity, fps @ 125°F	8.6	12.5	12.5	12.5
Liquor Rate, gpm	1200	900	900	900
L/G, gal/mcf	73	37	37	37
Percent Solids Recirculated	7-8	7.5-8.5	7-8	14.1-15.4
Effluent Residence Time, min	4.1	4.1	4.1	4.1
Stoichiometric Ratio, moles Ca added/mole SO_2 absorbed	1.00-1.03[a]	1.00-1.06[b]	0.98-1.05[c]	1.00-1.04[d]
Avg. % Lime Utilization, 100x moles SO_2 abs. /mole Ca added	99[a]	97[b]	99[c]	98[d]
Inlet SO_2 Concentration, ppm	3100-3900	2600-4000	2800-3600	3030-4100
Percent SO_2 Removal	76-84	69-82	78-94	76-89
Scrubber Inlet pH Range	6.85-7.1	7.85-8.1	7.8-8.1	7.8-8.1
Scrubber Outlet pH Range	5.1-5.4	4.9-5.3	5.1-5.4	4.9-5.2
Inlet O_2 Concentration, vol. %	5.5-6.5	5-8	4.5-7.5	5-7
Percent Sulfur Oxidized	14-25	15-32	5-25	15-25
Solids Disposal System	Clarifier & Centrifuge	Clarifier & Centrifuge	Clarifier & Centrifuge	Clarifier & Centrifuge
Loop Closure, % Solids Dischg.	51-59	57-62	53-59	55-60
Calculated Avg % Sulfate Saturation in Scrubber Inlet Liquor @ 50°C	45	95	75	95
Total Dissolved Solids, ppm	13,600-16,200	14,000-16,400	22,000-26,400	22,200-26,000
Total ΔP Range Excluding Mist Elimination System, in. H_2O	4.5-5.0	6.4-7.0	5.7-7.1	6.8-7.6
Mist Elimination System ΔP Range, in. H_2O	0.25-0.32	0.51-0.56	0.45-0.57	0.49-0.54
Mist Elimination System Configuration	3-pass, open-vane, 316L SS, chevron mist eliminator	3-pass, open-vane, 316L SS, chevron mist eliminator	3-pass, open-vane, 316L SS, chevron mist eliminator	3-pass, open-vane, 316L SS, chevron mist eliminator.
Absorbent	Lime slurried to 20 wt % with makeup water and added to downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt % with makeup water and added to downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt % with makeup water and added to downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt % with makeup water and added to downcomer. MgO dry fed to EHT.
Mist Eliminator Washing Scheme	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.
Scrubber Internals	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run. Estimated total actual bed height was 14.0 in.	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run. Estimated total actual bed height was 14.0 in.	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run. Estimated total actual bed height was 14.0 in.	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run. Estimated total actual bed height was 13.5 in.
System Changes Before Start of Run	Mist eliminator, bottom grid, walls below bottom grid, and outlet duct to reheater cleaned prior to run. No other changes.	No changes. No cleaning.	Mist eliminator and bottom grid cleaned prior to run. No other changes.	Mist eliminator cleaned. No other changes.
Method of Control	Scrubber inlet liquor pH controlled at 7.0 ± 0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.	Scrubber inlet liquor pH controlled at 8.0 ± 0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.	Scrubber inlet liquor pH controlled at 8.0 ± 0.2. Mg ion concentration in liquor controlled at $(6000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.	Scrubber inlet liquor pH controlled at 8.0 ± 0.2. Mg ion concentration in liquor controlled at $(6000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.
Run Philosophy	To observe the effect of low gas rate (high L/G), 20,500 acfm cf. 30,000 acfm for 601-2A, on SO_2 removal and sulfate saturation. All other operating conditions same as for Run 601-2A.	To observe if a scrubber inlet pH of 8.0 prevents the scaling which occurred at pH of 7.0 during Run 604-2A. Other test conditions same as Run 604-2A.	To see whether the TCA can be operated free of scale at 900 gpm liquor rate (cf. Runs 604-2A and 606-2A) by increasing Mg ion concentration.	To observe the effect of high percent solids recirculated (15% cf. 8% for 607-2A) on sulfate saturation. Other test conditions same as Run 607-2A.
Results	SO_2 removal averaged 80% and sulfate saturation 45% (cf. 92% and 50% for 601-2A). Inspection at 151 operating hours showed that mist eliminator was 1% restricted. Also, two of four slurry spray nozzles were completely plugged and scrubber effluent horizontal discharge line to EHT badly plugged by scale and solids, resulted probably from clean-up debris prior to run. [a] Total stoich. ratio for Ca & Mg is 1.02-1.05 (avg. alkali util. = 97 %).	The mist eliminator was 10% restricted at end of run (cf. 40% at end of 604-2A). Heavy scaling on bottom grid, but lighter scaling on scrubber walls and outlet duct to reheater than during Run 604-2A. [b] Total stoich. ratio for Ca & Mg is 1.02 - 1.08 (avg. alkali util. = 95%).	Mist eliminator 5% restricted after 136 hours (cf. 10% after 122 hours of Run 606-2A) and 8% restricted at end of run. Scaling lighter elsewhere than at end of Runs 606-2A or 604-2A. Sulfate saturation averaged 75% (cf. 95% for 606-2A and 90% for 604-2A). [c] Total stoich. ratio for Ca & Mg is 1.01 - 1.09 (avg. alkali util. = 95%).	Sulfate saturation averaged 95% (cf. 75% for Run 607-2A). No inspection was made at the end of the run. [d] Total stoich. ratio for Ca & Mg is 1.04-1.09 (avg. alkali util. = 94%).

Table H-2 (continued)

SUMMARY OF LIME TESTS ON THE TCA SYSTEM

Run Number	608-2B	609-2A	610-2A	611-2A
Start-of-Run Date	9/6/76	9/13/76	9/24/76	10/7/76
End-of-Run Date	9/13/76	9/24/76	10/7/76	10/12/76
On Stream Hours	151	259	280	111
Gas Rate, acfm @ 300°F	30,000	30,000	30,000	30,000
Gas Velocity, fps @ 125°F	12.5	12.5	12.5	12.5
Liquor Rate, gpm	900	900	900	900
L/G, gal/mcf	37	37	37	37
Percent Solids Recirculated	14.2-15.5	7.6-8.6	7.4-8.4	7.3-8.7
Effluent Residence Time, min	5.4	5.4	5.4	4.1
Stoichiometric Ratio, moles Ca added/mole SO_2 absorbed	1.01-1.07[a]	0.96-1.04[b]	1.00-1.05[c]	1.00-1.06[d]
Avg. % Lime Utilization, 100x moles SO_2 abs./mole Ca added	96[a]	100[b]	98[c]	97[d]
Inlet SO_2 Concentration, ppm	2600-3600	2500-3600	2400-3450	2500-3300
Percent SO_2 Removal	90-99	70-80	77-91	77-85
Scrubber Inlet pH Range	7.8-8.1	6.8-7.15	7.8-8.15	7.85-8.1
Scrubber Outlet pH Range	5.4-6.2	4.8-5.1	5.1-5.35	4.9-5.5
Inlet O_2 Concentration, vol. %	5-9	5-7.5	6-9	5-7
Percent Sulfur Oxidized	8-18	10-26	2-12	20-40
Solids Disposal System	Clarifier & Centrifuge	Clarifier & Centrifuge	Clarifier & Filter	Clarifier & Filter
Loop Closure, % Solids Dischg.	52-56	55-63	53-67	55-65
Calculated Avg. % Sulfate Saturation in Scrubber Inlet Liquor @ 50°C	11	60	40	95
Total Dissolved Solids, ppm	19,800-24,000	14,400-17,700	14,400-18,200	18,600-21,000
Total ΔP Range Excluding Mist Elimination System, in. H_2O	5.9-6.7	5.6-6.5	5.6-6.1	5.9-7.2
Mist Elimination System ΔP Range, in. H_2O	0.48-0.53	0.48-0.53	0.47-0.53	0.48-0.53
Mist Elimination System Configuration	3-pass, open-vane, 316L SS, chevron mist eliminator.	3-pass, open-vane, 316L SS, chevron mist eliminator.	3-pass, open-vane, 316L SS, chevron mist eliminator.	3-pass, open-vane, 316L SS, chevron mist eliminator.
Absorbent	Lime slurried to 20 wt % with makeup water and added to downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt % with makeup water and added to downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt % with makeup water and added to downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt % with makeup water and added to downcomer. MgO dry fed to EHT.
Mist Eliminator Washing Scheme	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.
Scrubber Internals	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run. Estimated total actual bed height was 13.5 in.	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run. Estimated total actual bed height was 13.5 in.	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run. Estimated total actual bed height was 13.0 in.	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run. Estimated total actual bed height was 12.5 in.
System Changes Before Start of Run	No changes. No cleaning.	No changes. No cleaning.	No changes. No cleaning.	No changes. No cleaning.
Method of Control	Scrubber inlet liquor pH controlled at 8.0±0.2. Mg ion concentration in liquor controlled at $(4000 + \frac{(ppm\ Cl^-)}{2.92})$ ppm.	Scrubber inlet liquor pH controlled at 7.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(ppm\ Cl^-)}{2.92})$ ppm.	Scrubber inlet liquor pH controlled at 8.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(ppm\ Cl^-)}{2.92})$ ppm.	Scrubber inlet liquor pH controlled at 8.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(ppm\ Cl^-)}{2.92})$ ppm.
Run Philosophy	This run is a continuation of Run 608-2A except that a step change in EHT residence time from 4.1 to 5.4 min. was made to observe the effect on sulfate saturation.	To observe if the higher 5.4 min. residence time results in sulfate unsaturated operation with 900 gpm slurry rate and 2000 ppm effective Mg^{++} conc. (cf. Run 604-2A with a 4.1 min. residence time).	To observe if a residence time of 5.4 min. prevents the sulfate saturated mode of operation which occurred with a 4.1 min. residence time during Run 606-2A. Other test conditions same as Run 606-2A.	To confirm the sulfate scaling mode of operation during Run 606-2A at 4.1 min. residence time. Run conditions identical with those of Run 606-2A.
Results	Sulfate saturation dropped to an average 11% (cf. 95% for 608-2A). SO_2 removal averaged 95% (cf. 83% for Run 608-2A). The mist eliminator was 2% restricted at the end of this run. [a] Total stoich. ratio for Ca & Mg is 1.05-1.11 (avg. alkali util. = 93%).	Sulfate saturation was 60% (cf. 90% for Run 604-2A). Mist eliminator was 3% restricted at end of run after 259 hours, down from an initial 2% (cf. 40% for 604-2A). [b] Total stoich. ratio for Ca & Mg is 0.98-1.06 (avg. alkali util. = 98%).	Sulfate saturation was 40% (cf. 95% for Run 606-2A), and sulfur oxidation averaged 7% (cf. 24% for Run 606-2A). The mist eliminator was 2% restricted after 207 hours, from an initial 3%. [c] Total stoich. ratio for Ca & Mg is 1.02-1.07 (avg. alkali util. = 95%).	Mist eliminator 6% restricted at end of run. Some scale in reheater and on leading edge of I.D. fan damper. Sulfate saturation was 95% (cf. 95% for Run 606-2A). [d] Total stoich. ratio for Ca & Mg is 1.03-1.09 (avg. alkali util. = 95%).

Table H-2 (continued)

SUMMARY OF LIME TESTS ON THE TCA SYSTEM

Run Number	612-2A	613-2A	614-2A	615-2A
Start-of-Run Date	10/12/76	10/18/76	10/22/76	10/28/76
End-of-Run Date	10/18/76	10/21/76	10/28/76	11/3/76
On Stream Hours	139	67	139	110
Gas Rate, acfm @ 300°F	30,000	30,000	30,000	30,000
Gas Velocity, fps @ 125°F	12.5	12.5	12.5	12.5
Liquor Rate, gpm	900	1200	900	1200
L/G, gal/mcf	37	50	37	50
Percent Solids Recirculated	7.4-8.5	7.6-8.7	7.8-8.6	7.7-8.6
Effluent Residence Time, min	3	3	16	12
Stoichiometric Ratio, moles Ca added/mole SO_2 absorbed	0.98-1.02$^{(a)}$	0.98-1.03$^{(b)}$	1.01-1.0[illegible]$^{(c)}$	0.98-1.06$^{(d)}$
Avg. % Lime Utilization, 100x moles SO_2 abs./mole Ca added	100$^{(a)}$	100$^{(b)}$	97$^{(c)}$	98$^{(d)}$
Inlet SO_2 Concentration, ppm	2700-3400	2300-3800	3100-4200	2500-3700
Percent SO_2 Removal	78-84	79-90	71-80	84-92
Scrubber Inlet pH Range	7.85-8.1	6.8-7.1	7.8-8.3	6.8-7.4
Scrubber Outlet pH Range	4.7-5.3	4.7-4.85	-	4.8-5.15
Inlet O_2 Concentration, vol.%	5-7	6-10	5.5-9	6-12.5
Percent Sulfur Oxidized	27-37	25-44	5-18	9-25
Solids Disposal System	Clarifier & Centrifuge	Clarifier & Centrifuge	Clarifier & Centrifuge	Clarifier & Centrifuge
Loop Closure, % Solids Dischg.	57-61	58-61	55-61	59-67
Calculated Avg. % Sulfate Saturation in Scrubber Inlet Liquor @ 50°C	95	95	90	95
Total Dissolved Solids, ppm	20,000-22,600	18,800-22,200	17,600-19,600	17,600-20,400
Total ΔP Range Excluding Mist Elimination System, in. H_2O	6.4-7.9	7.2-8.2	5.6-6.4	7.3-8.3
Mist Elimination System ΔP Range, in. H_2O	0.53-0.57	0.57-0.61	0.45-0.50	0.46-0.56
Mist Elimination System Configuration	3-pass, open-vane, 316L SS, chevron mist eliminator.	3-pass, open-vane, 316L SS, chevron mist eliminator.	3-pass, open-vane, 316L SS, chevron mist eliminator.	3 pass, open-vane, 316L SS, chevron mist eliminator.
Absorbent	Lime slurried to 20 wt.% with makeup water and added to downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt.% with makeup water and added to downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt.% with makeup water and added to downcomer. MgO dry fed to EHT.	Lime slurried to 20 wt.% with makeup water and added to downcomer. MgO dry fed to EHT.
Mist Eliminator Washing Scheme	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 7[illegible] min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.
Scrubber Internals	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run. Estimated total actual bed height was 12.5 in.	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run. Estimated total actual bed height was 12.0 in.	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run. Estimated total actual bed height was 12.0 in.	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run. Estimated total actual bed height was 11.5 in.
System Changes Before Start of Run	Mist eliminator cleaned. No other changes.	The bottom grid of the TCA was cleaned. No other changes.	Mist eliminator cleaned. No other changes.	Solids that had fallen on top of the mist eliminator during Run 614-2A from outlet duct were removed, reducing eliminator restriction from 4% to 1%. Otherwise mist eliminator not cleaned. No other changes.
Method of Control	Scrubber inlet liquor pH controlled at 8.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.	Scrubber inlet liquor pH controlled at 7.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.	Scrubber inlet liquor pH controlled at 8.0±0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.	Scrubber inlet liquor pH controlled at 7.0± 0.2. Mg ion concentration in liquor controlled at $(2000 + \frac{(\text{ppm Cl}^-)}{2.92})$ ppm.
Run Philosophy	To observe the effect of residence time (3 min.) on sulfate saturation. Compare with Runs 611-2A & 606-2A (4.1 min.) and Run 610-2A (5.4 min) all at otherwise same conditions.	To observe the effect of lowering the residence time from 4.1 min. (Run 601-2A) to 3 min., with all other conditions the same as for Run 601-2A.	To observe the effect of high residence time (16 min.) compared with low residence time (4.1 min. during Run 606-2A) on sulfate saturation. All other conditions the same as for Run 606-2A.	To observe the effect of a 12 min. residence time on sulfate saturation in comparison with Runs 601-2A (4.1 min.) and 613-2A (3.0 min.). All other conditions same as for Run 601-2A.
Results	Sulfate saturation for this run was the same as for Runs 611-2A & 606-2A at 95%, cf. with 40% during Run 610-2A. The mist eliminator was 5% restricted at the end of the run. (a) Total stoich. ratio for Ca & Mg is 1.01-1.05 (avg. alkali util. = 97%).	Sulfate saturation was 95% (cf. 50% for Run 601-2A). Mist eliminator restriction increased by 7% over the run to 12%. (cf. <1% restriction increase during 177 hours of Run 601-2A). (b) Total stoich. ratio for Ca & Mg is 1.01-1.06 (avg. alkali util. = 97%).	Sulfate saturation was 90% (cf. 95% during Run 606-2A). The mist eliminator was 4% restricted mostly with loose solids/scale from outlet duct (cf. 10% at end of Run 606-2A). Also there was scaling of lower walls of TCA. (c) Total stoich. ratio for Ca & Mg is 1.03-1.09 (avg. alkali util. = 94%).	Sulfate saturation averaged 95% (cf. 50% for Run 601-2A and 95% for Run 613-2A). The mist eliminator was 2% restricted at end of run. Heavy scale in reheater. (d) Total stoich. ratio for Ca & Mg is 1.00-1.08 (avg. alkali util. = 96%).

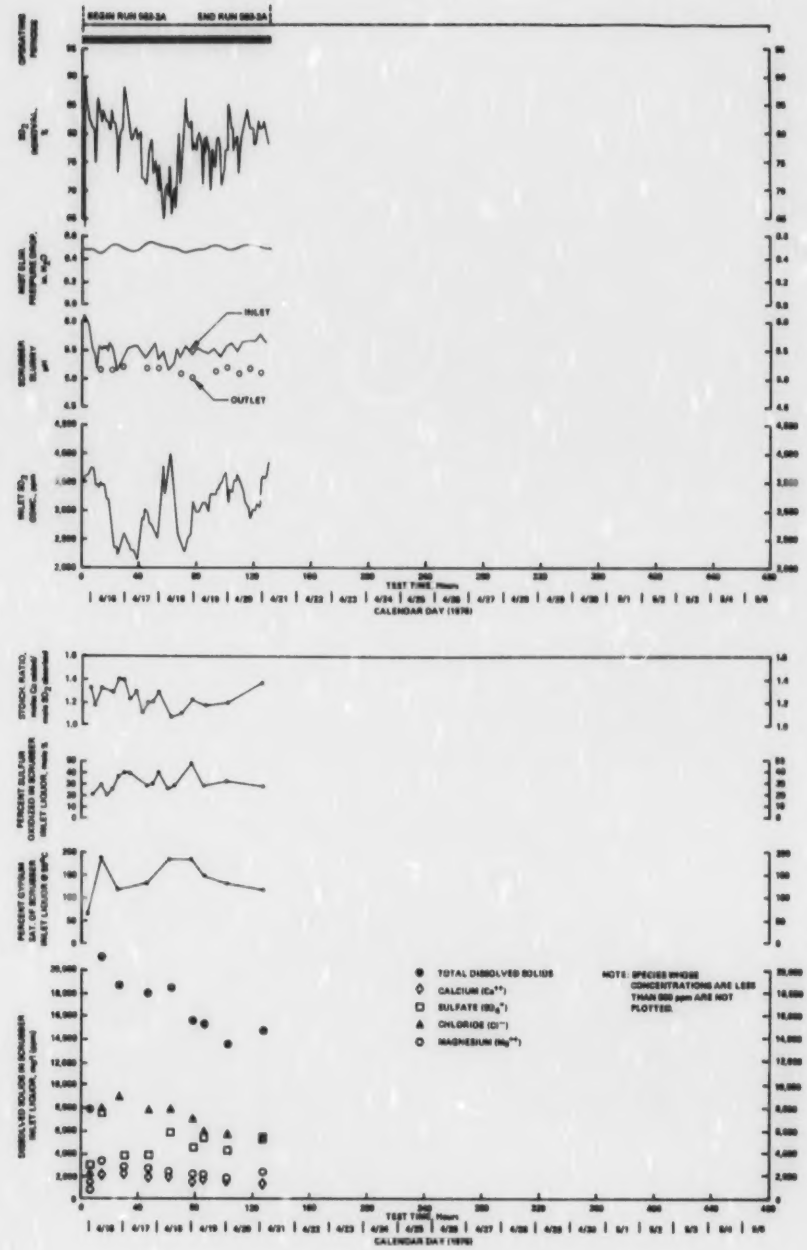
Table H-2 (continued)

SUMMARY OF LIME TESTS ON THE TCA SYSTEM

Run Number	616-2A	617-2A	
Start-of-Run Date	11/5/76	11/15/76	
End-of-Run Date	11/13/76	11/22/76	
On Stream Hours	174	159	
Gas Rate, acfm @ 300°F	30,000	30,000	
Gas Velocity, fps @ 125°F	12.5	12.5	
Liquor Rate, gpm	1200	1200	
L/G, gal/mcf	50	50	
Percent Solids Recirculated	7.7-8.1	14.0-15.5	
Effluent Residence Time, min	12	12	
Stoichiometric Ratio, moles Ca added/mole SO_2 absorbed	1.05-1.15	1.04-1.11	
Avg. % Lime Utilization, 100x moles SO_2 abs./mole Ca added	91	93	
Inlet SO_2 Concentration, ppm	2800-3800	2700-3500	
Percent SO_2 Removal	66-78	74-85	
Scrubber Inlet pH Range	7.8-8.3	7.9-8.2	
Scrubber Outlet pH Range	4.2-4.6	4.3-4.7	
Inlet O_2 Concentration, vol. %	5-8.5	4.5-9	
Percent Sulfur Oxidized	7-32	5-18	
Solids Disposal System	Clarifier & Centrifuge	Clarifier & Centrifuge	
Loop Closure, % Solids Dischg.	50-63	54-60	
Calculated Avg % Sulfate Saturation in Scrubber Inlet Liquor @ 50°C	115	110	
Total Dissolved Solids, ppm	7800-10,000	8000-11,000	
Total ΔP Range Excluding Mist Elimination System, in H_2O	6.8-8.0	8.0-9.1	
Mist Elimination System ΔP Range, in. H_2O	0.42-0.51	0.42-0.49	
Mist Elimination System Configuration	3-pass, open-vane, 316 L SS, chevron mist eliminator.	3 pass, open-vane, 316L SS, chevron mist eliminator.	
Absorbent	Lime slurried to 20 wt.% with makeup water and added to downcomer.	Lime slurried to 20 wt % with makeup water and added to downcomer.	
Mist Eliminator Washing Scheme	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.	Top washed sequentially with makeup water. Each nozzle (6 total) on 4 minutes (at 0.55 gpm/sq. ft.) with 76 min. off between nozzles. Bottom washed intermittently with makeup water at 1.5 gpm/sq. ft. for 6 minutes every 4 hours.	
Scrubber Internals	3 beds (4 grids) with nominally 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run. The total actual bed height measured during shutdown at 133 oper. hours was 11.0 in.	3 beds (4 grids) with 5 inches spheres/bed. All beds worn nitrile foam spheres from previous run.	
System Changes Before Start of Run	Clarifier dumped and scrubber system cleaned to purge system of magnesium ion. Mist eliminator cleaned.	Used spheres added towards end of Run 616-2A to increase total bed height to 15 inches. No cleaning.	
Method of Control	Scrubber inlet liquor pH controlled at 8.0 ± 0.2.	Scrubber inlet liquor pH controlled at 8.0 ± 0.2.	
Run Philosophy	To observe TCA performance with lime scrubbing (no MgO addition) under typical operating conditions.	To observe if 15% solids recirculated (cf. 8% in Run 616-2A) decreases scaling potential shown during Run 616-2A. All other conditions same for both runs.	
Results	SO_2 removal averaged 72%, and lime utilization 91%, at an average inlet SO_2 concentration of 3300 ppm. The mist eliminator was 2% restricted after 133 hrs of operation due primarily to fall-out solids. These were removed and at end of run it was < 1% restricted. Some gypsum scale formed on wall below bottom grid.	Sulfate saturation averaged 110% (cf. 115% during Run 616-2A). SO_2 removal averaged 80%, lime utilization 93%, inlet SO_2 conc. 3100 ppm (cf. 72%, 91%, and 3300 ppm for Run 616-2A). The mist eliminator was < 1% restricted at end of run. Gypsum scale found at end of Run 616-2A was diminishing.	

APPENDIX I

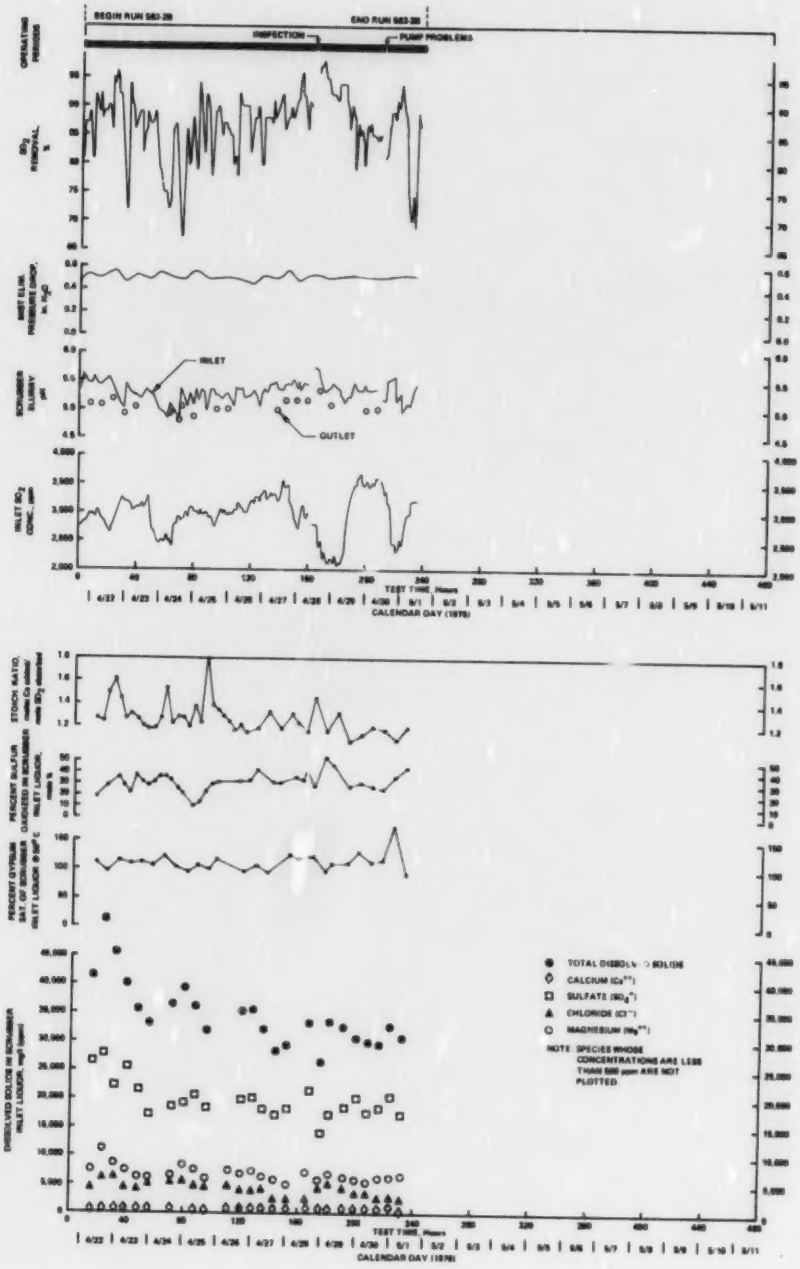
GRAPHICAL OPERATING DATA FROM THE TCA TESTS



Gas Rate = 30,000 acfm @ 300 °F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 1200 gpm
L/G = 50 gal/mcf
EHT Residence Time = 3 min
Three Stages, 5 in. spheres/stage
Note: Only solids data points with
ionic imbalances between ± 8.5%
are plotted.

Percent Solids Recirculated = 13.2-16.4
Total Pressure Drop, Excluding Mist Elim.
= 8.5-10.5 in. H$_2$O
Discharge (Clarifier) Solids
Concentration = 33-41 wt %
Limestone Addition to EHT

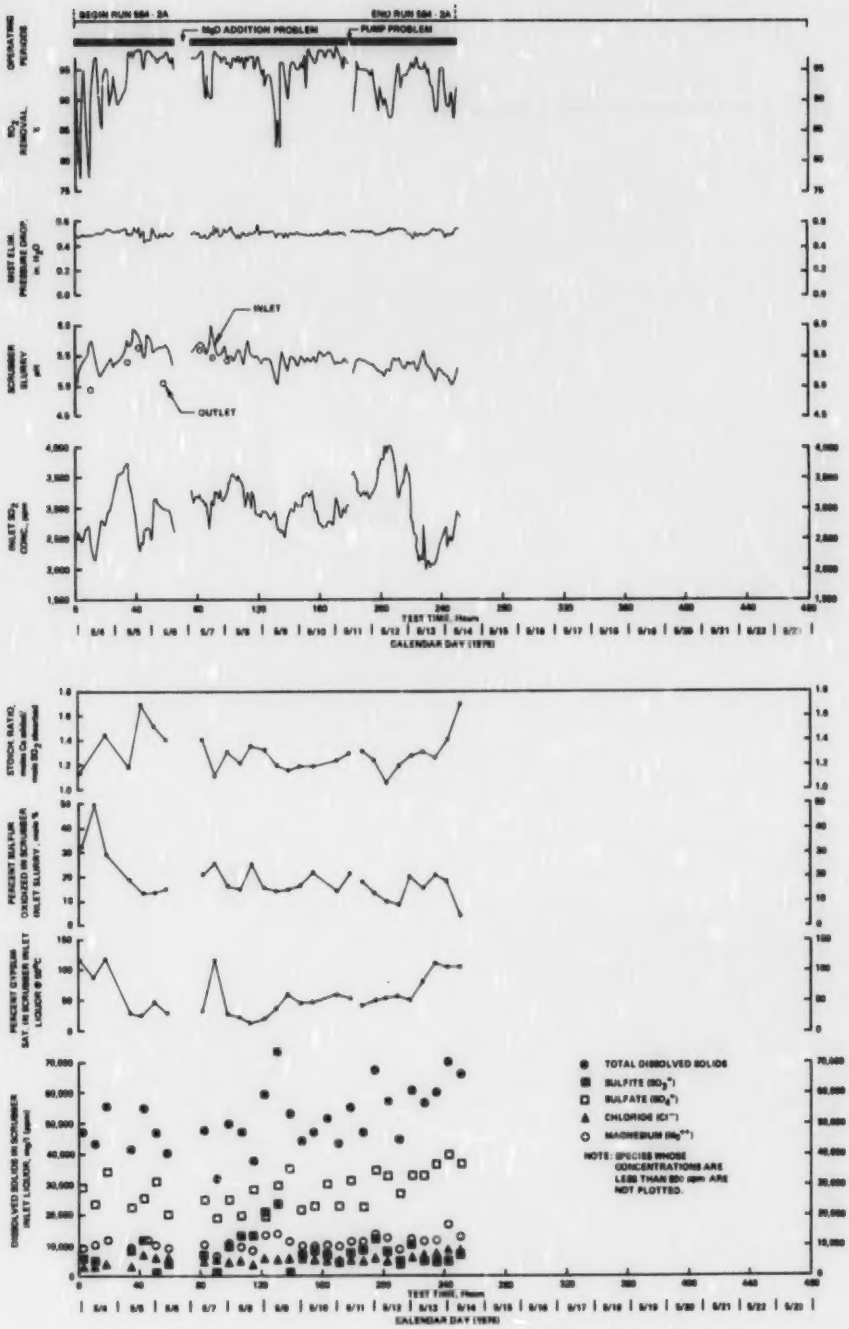
Figure I-1. OPERATING DATA FOR TCA RUN 583-2A



Gas Rate = 30,000 acfm @ 300 °F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 1200 gpm
L/G = 50 gal/mcf
EHT Residence Time = 3 min
Three Stages, 5 in. spheres/stage
Note: Only solids data points with
ionic imbalances between ± 8.5%
are plotted.

Percent Solids Recirculated = 13.0-17.8 wt %
Total Pressure Drop, Excluding Mist Elim.
= 8.5-11.5 in. H_2O
Discharge (Centrifuge) Solids
Concentration = 55-64 wt %
Limestone and MgO Addition to EHT

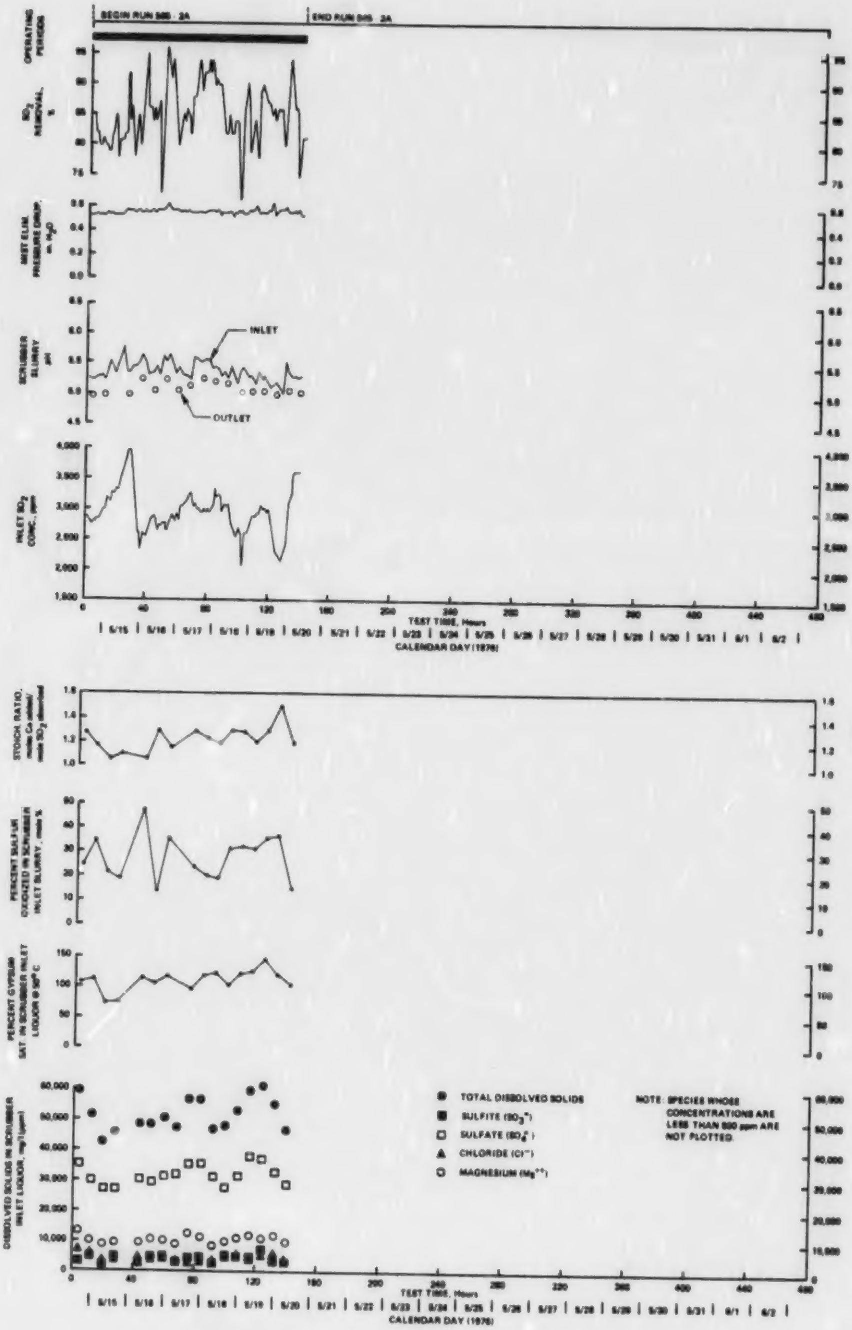
Figure I-2. OPERATING DATA FOR TCA RUN 583-28



Gas Rate = 30,000 acfm @ 300 °F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 1200 gpm
L/G = 50 gal/mcf
EHT Residence Time = 3.0/4.1 min
Three Stages, 5 in. bed height/stage

Percent Solids Recirculated = 14-18 wt %
Total Pressure Drop, Excluding Mist Elim.
= 7.5-10.5 in. H_2O
Discharge (Clarifier/Centrifuge) Solids
Concentration = 32-38 wt % (Clar.)
& 53-61 wt % (Cent.)
Limestone Addition to Downcomer and
MgO Addition to EHT

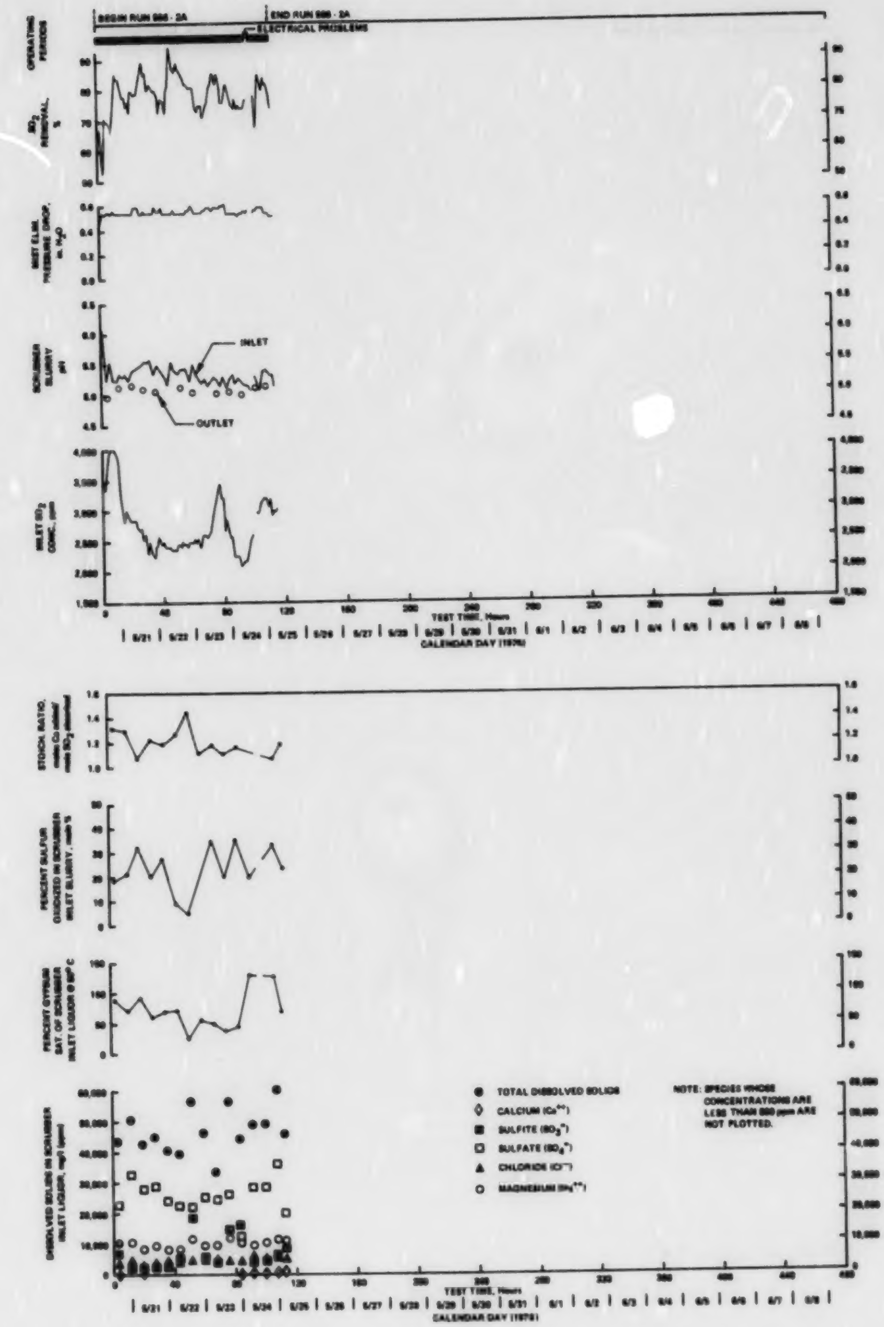
Figure I-3. OPERATING DATA FOR TCA RUN 584-2A



Gas Rate = 30,000 acfm @ 300 °F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 900 gpm
L/G = 37 gal/mcf
EHT Residence Time = 4.1 min
Three Stages, 5 in. bed height/stage

Percent Solids Recirculated = 13-16 wt %
Total Pressure Drop, Excluding Mist Elim.
= 7.0-8.6 in. H_2O
Discharge (Clarifier) Solids Concentration
= 33-38 wt %
Limestone Addition to Downcomer and
MgO Addition to EHT

Figure I-4. OPERATING DATA FOR TCA RUN 585-2A

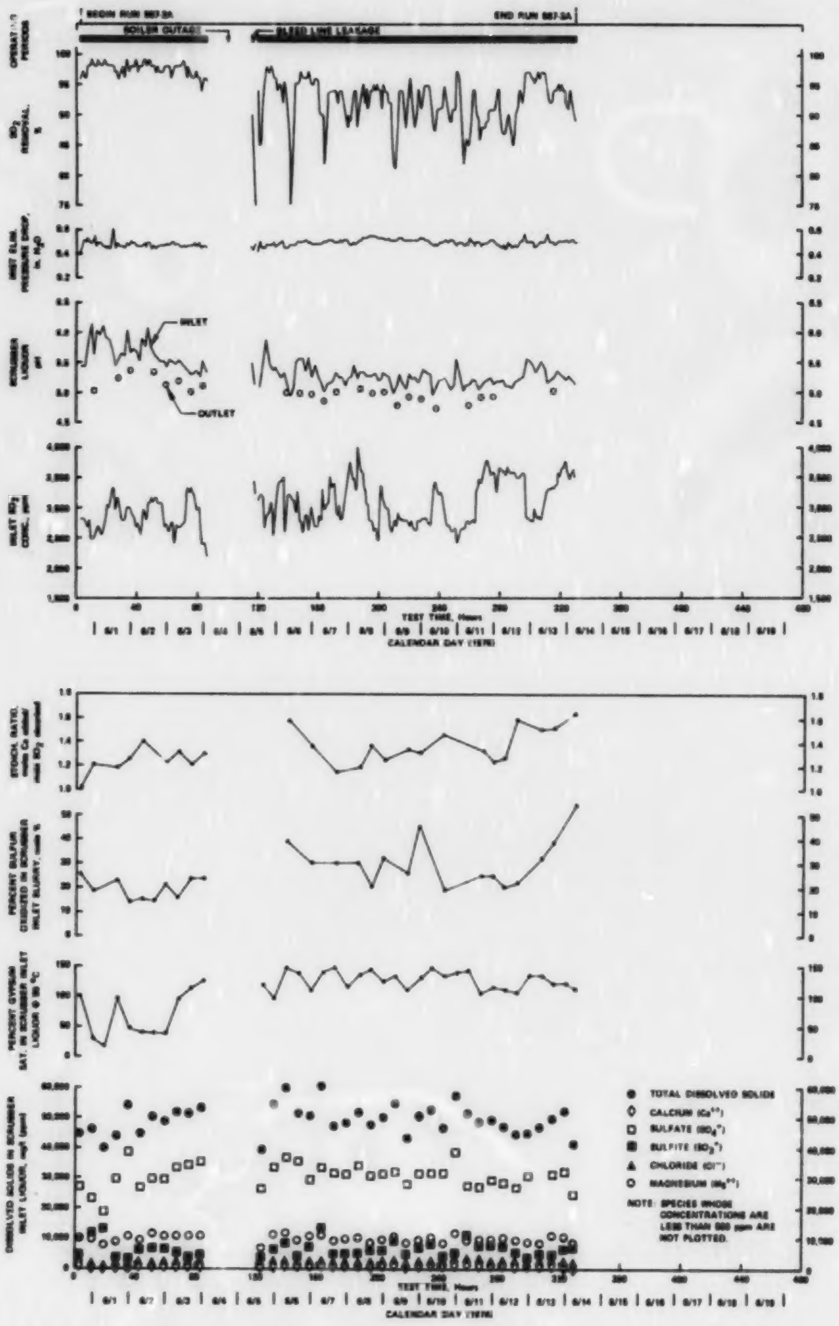


NOTE: SPECIES WHOSE CONCENTRATIONS ARE LESS THAN 500 ppm ARE NOT PLOTTED.

Gas Rate = 30,000 acfm @ 300 °F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 1200 gpm
L/G = 50 gal/mcf
EHT Residence Time ~ 4.1 min
No beds of spheres in place (4 grids only)

Percent Solids Recirculated = 14-16 wt %
Total Pressure Drop, Excluding Mist Elim.
= 3.3-3.7 in. H_2O
Discharge (Clarifier) Solids Concentration
= 36-37 wt %
Limestone Addition to Downcomer and
MgO Addition to EHT

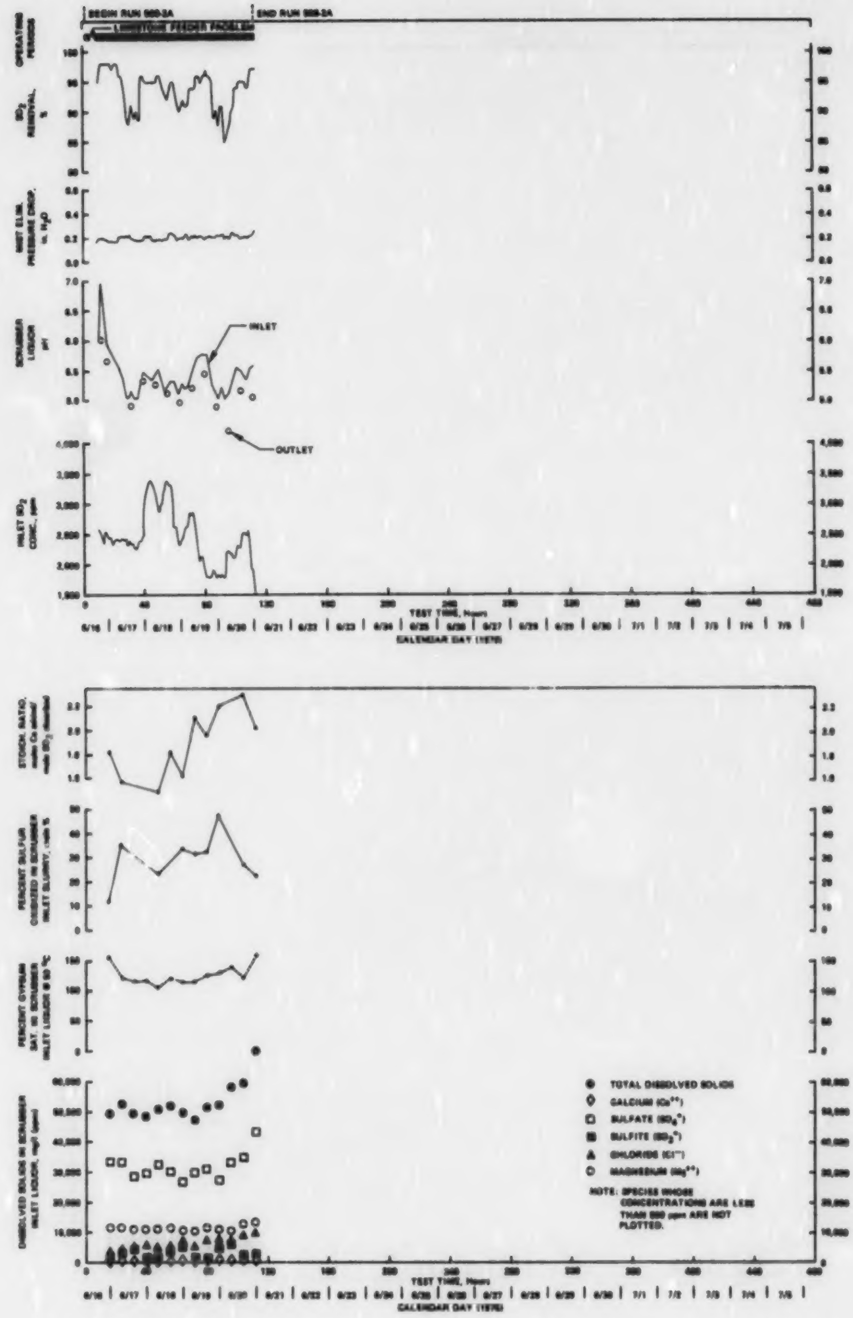
Figure I-5. OPERATING DATA FOR TCA RUN 586-2A



Gas Rate = 30,000 acfm @ 300 °F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 1200 gpm
L/G = 50 gal/mcf
EHT Residence Time = 4.1 min
3 Bed, 5 in. spheres/bed

Percent Solids Recirculated = 8 - 11 wt %
Total Pressure Drop, Excluding Mist Elim.
= 8.1-12.5 in. H_2O
Discharge (Clar. & Cent. in Parallel) Solids
Concentration = 30-55 wt %
Limestone Addition to Downcomer
and MgO Addition to EHT

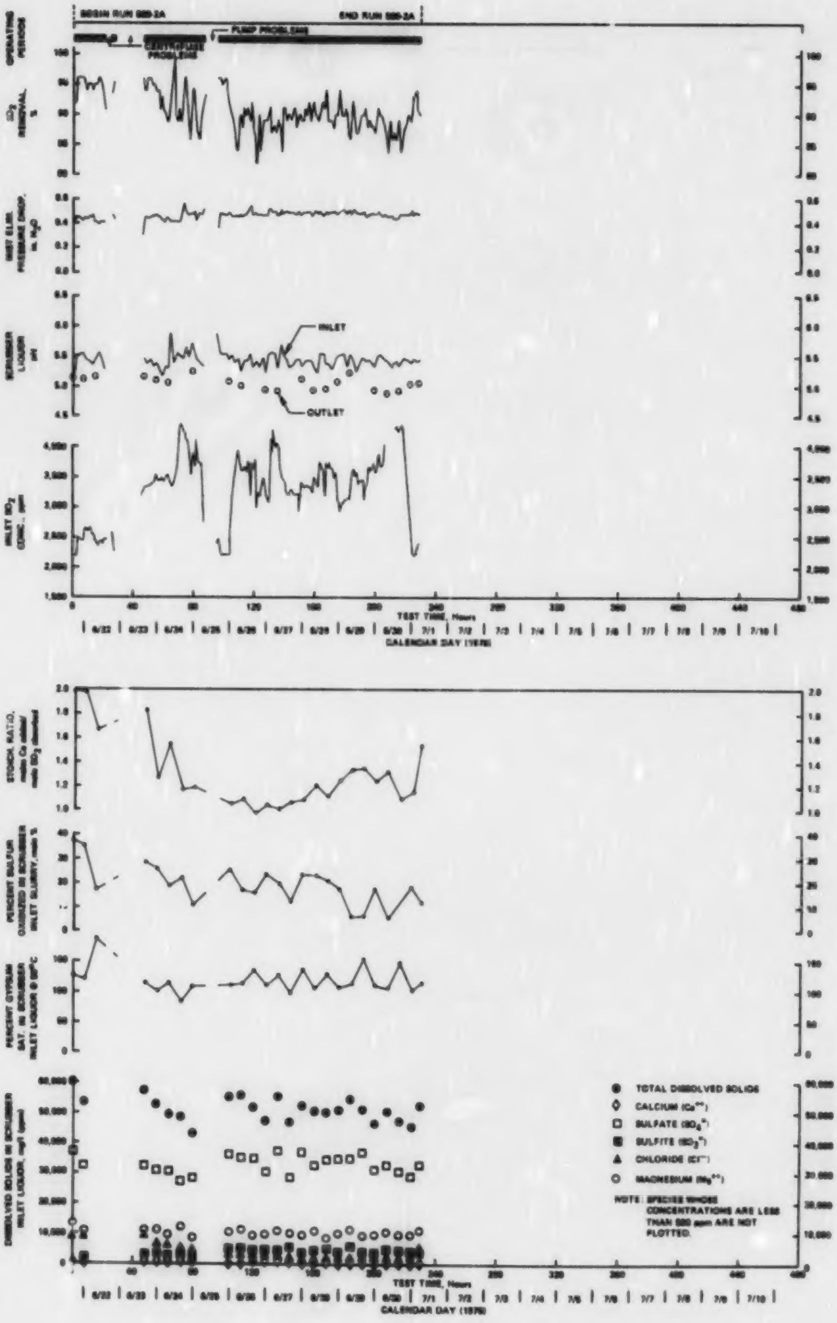
Figure I-6. OPERATING DATA FOR TCA RUN 587-2A



Gas Rate = 20,500 acfm @ 300° F
Gas Velocity = 8.6 ft/sec
Liquor Rate = 1200 gpm
L/G = 73 gal/mcf
EHT Residence Time = 4.1 min
3 Bed, 5 in. sphere/bed

Percent Solids Recirculated = 13-16 wt %
Total Pressure Drop, Excluding Mist Elim.
= 5.5-5.7 in. H_2O
Discharge (Centrifuge) Solids
Concentration = 60-68 wt %
Limestone Addition to Downcomer
and MgO Addition to EHT

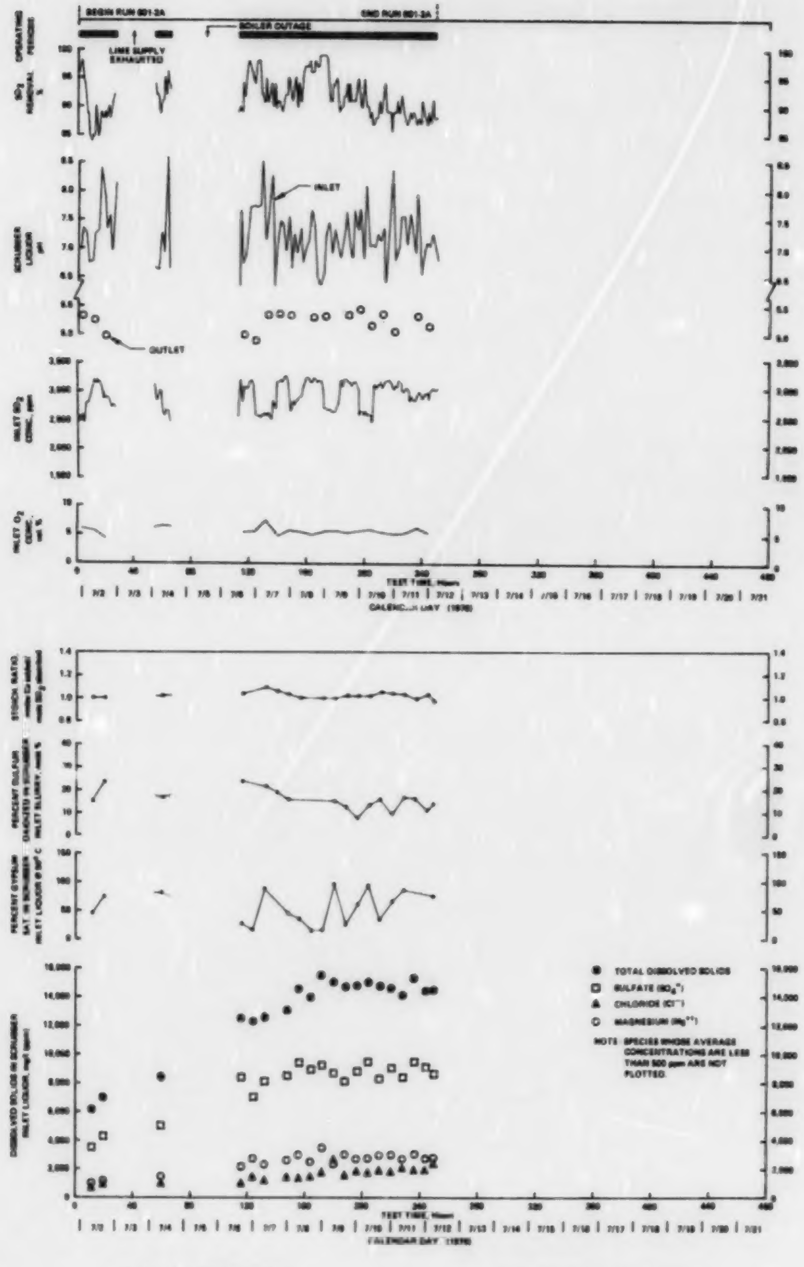
Figure I-7. OPERATING DATA FOR TCA RUN 588-2A



Gas Rate = 30,000 acfm @ 300 °F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 1200 gpm
L/G = 50 gal/mcf
EHT Residence Time = 4.1 min
3 Bed, 5 in. spheres/bed

Percent Solids Recirculated = 14-16 wt %
Total Pressure Drop, Excluding Mist Elim.
= 7.7-8.9 in. H_2O
Discharge (Centrifuge) Solids
Concentration = 52-61 wt %
Limestone Addition to Downcomer
and MgO Addition to EHT

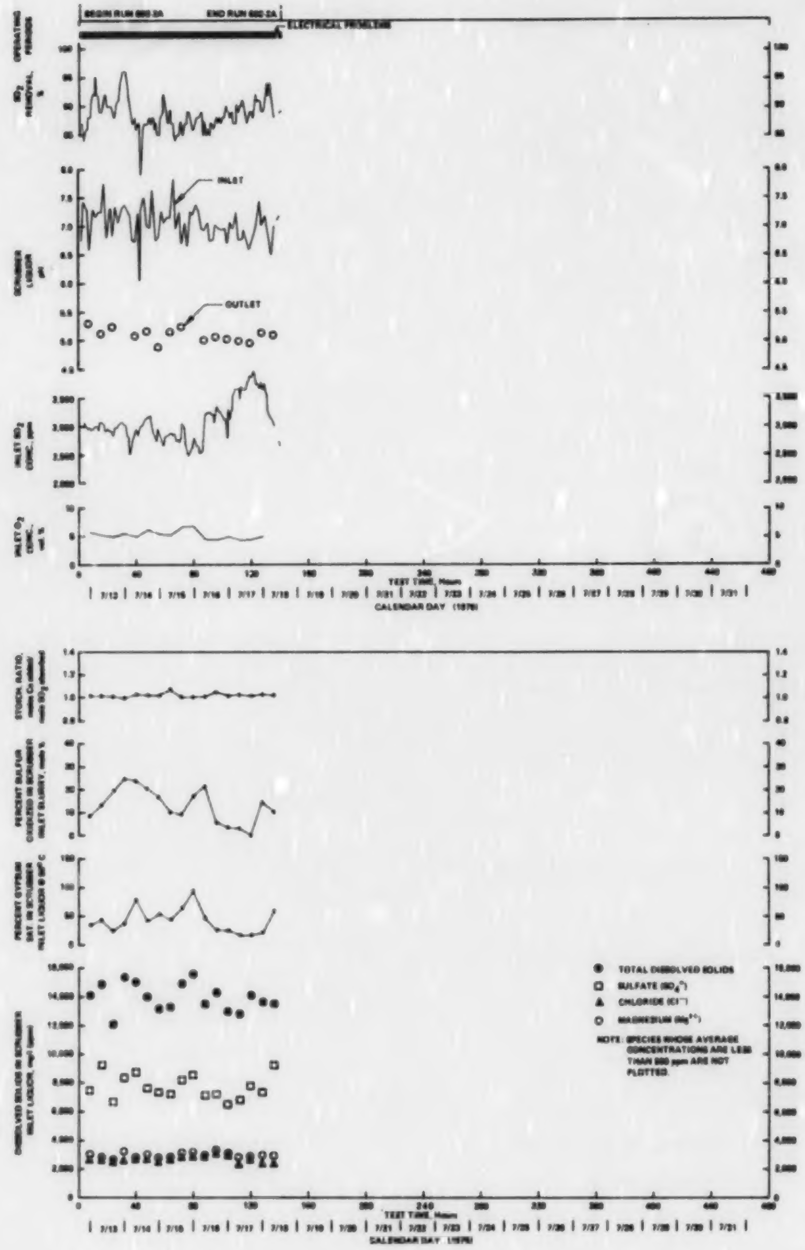
Figure I-8. OPERATING DATA FOR TCA RUN 589-2A



Gas Rate = 30,000 acfm @ 300° F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 1200 gpm
L/G = 50 gal/mcf
EHT Residence Time = 4.1 min
3 Beds, 5 in. spheres/bed

Percent Solids Recirculated = 8-9 wt %
Total Pressure Drop, Excluding Mist Elim.
= 7.9-8.5 in. H_2O
Mist Elim. Pressure Drop = 0.47-052 in. H_2O
Discharge (Clarifier & Centrifuge) Solids
Concentration = 54-60 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

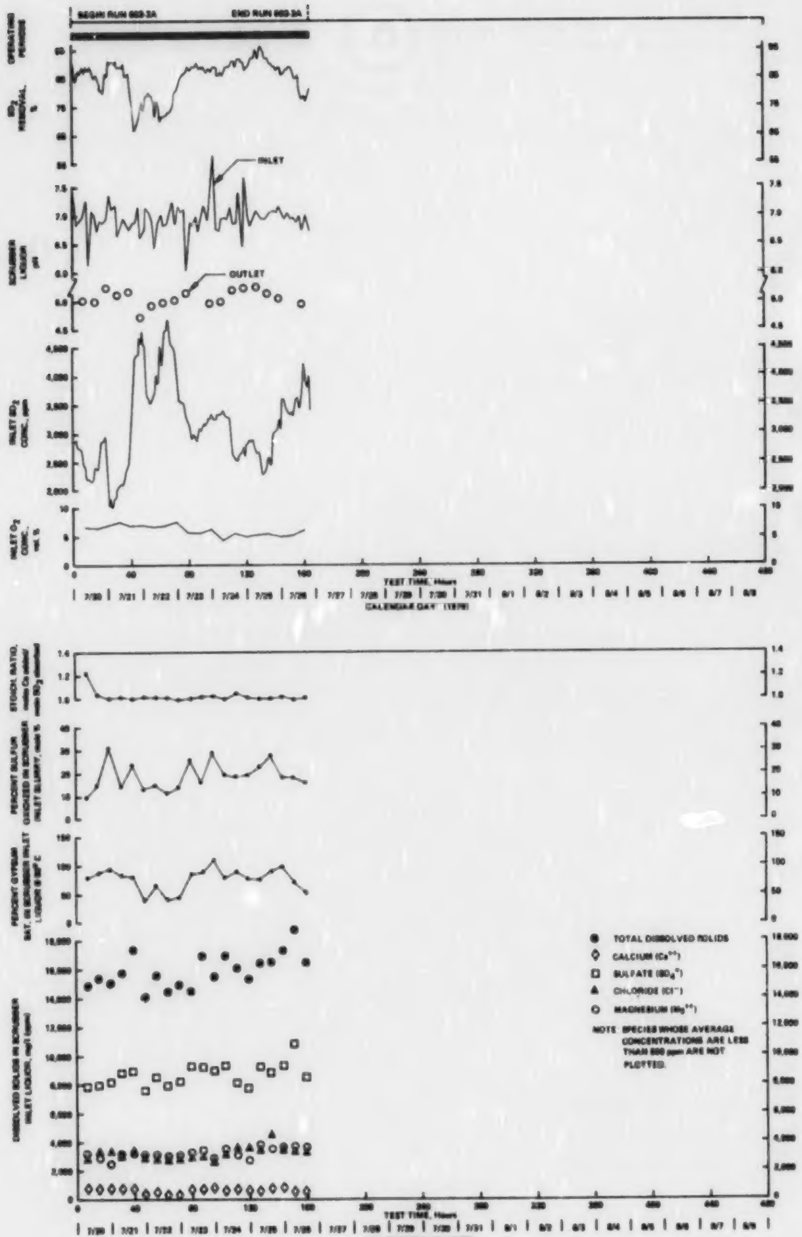
Figure I-9. OPERATING DATA FOR TCA RUN 601 - 2A



Gas Rate = 30,000 acfm @ 300° F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 1200 gpm
L/G = 50 gal/mcf
EHT Residence Time = 4.1 min
3 Beds, 5 in. spheres/bed

Percent Solids Recirculated = 14-16 wt. %
Total Pressure Drop, Excluding Mist Elim.
= 7.9-8.7 in. H_2O
Mist Elim. Pressure Drop = 0.49-0.51 in. H_2O
Discharge (Clarifier & Centrifuge) Solids
Concentration = 57-60 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

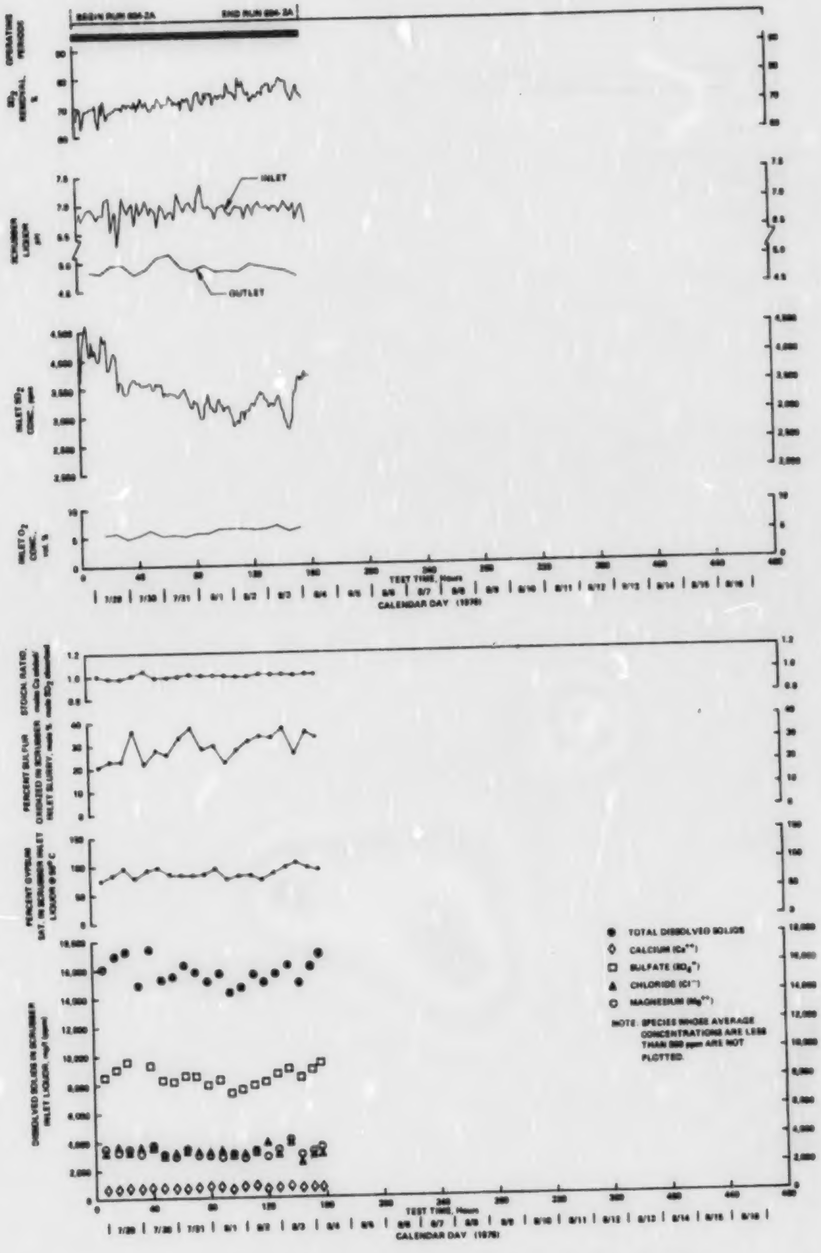
Figure I - 10. OPERATING DATA FOR TCA RUN 602 - 2A



Gas Rate = 30,000 acfm @ 300° F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 1200 gpm
L/G = 50 gal/mcf
EHT Residence Time = 4.1 min
3 Beds, 5 in. spheres/bed

Percent Solids Recirculated = 7-8 wt %
Total Pressure Drop, Excluding Mist Elim.
= 7.5-9.1 in. H_2O
Mist Elim. Pressure Drop = 0.40-0.53 in. H_2O
Discharge (Clarifier & Centrifuge) Solids
Concentration = 58-63 wt %
Lime and MgO Addition to EHT

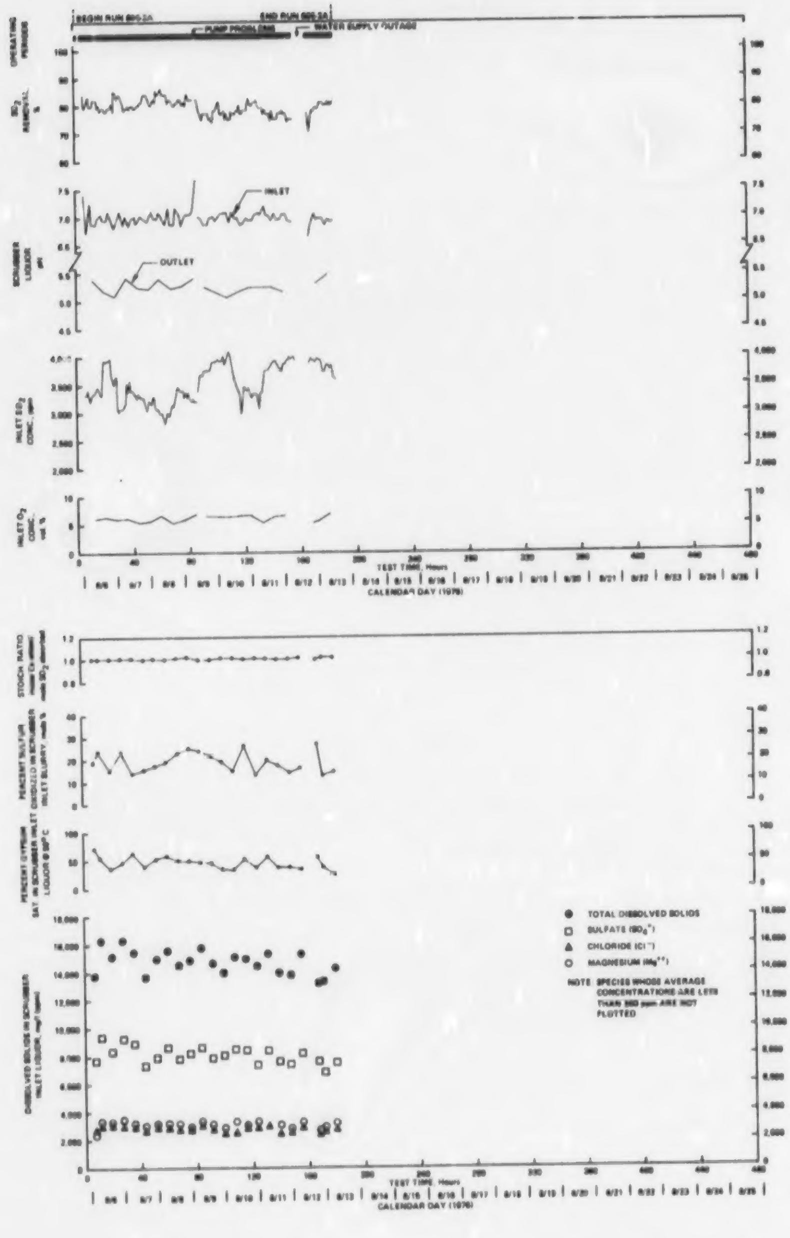
Figure I-11. OPERATING DATA FOR TCA RUN 603 - 2A



Gas Rate = 30,000 acfm @ 300° F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 900 gpm
L/G = 37 gal/mcf
EHT Residence Time = 4.1 min
3 Beds, 5 in. spheres/bed

Percent Solids Recirculated = 7-8 wt %
Total Pressure Drop, Excluding Mist Elim.
= 6.6-7.9 in. H_2O
Mist Elim. Pressure Drop = 0.57-0.88 in. H_2O
Discharge (Clarifier & Centrifuge) Solids
Concentration = 58-62 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

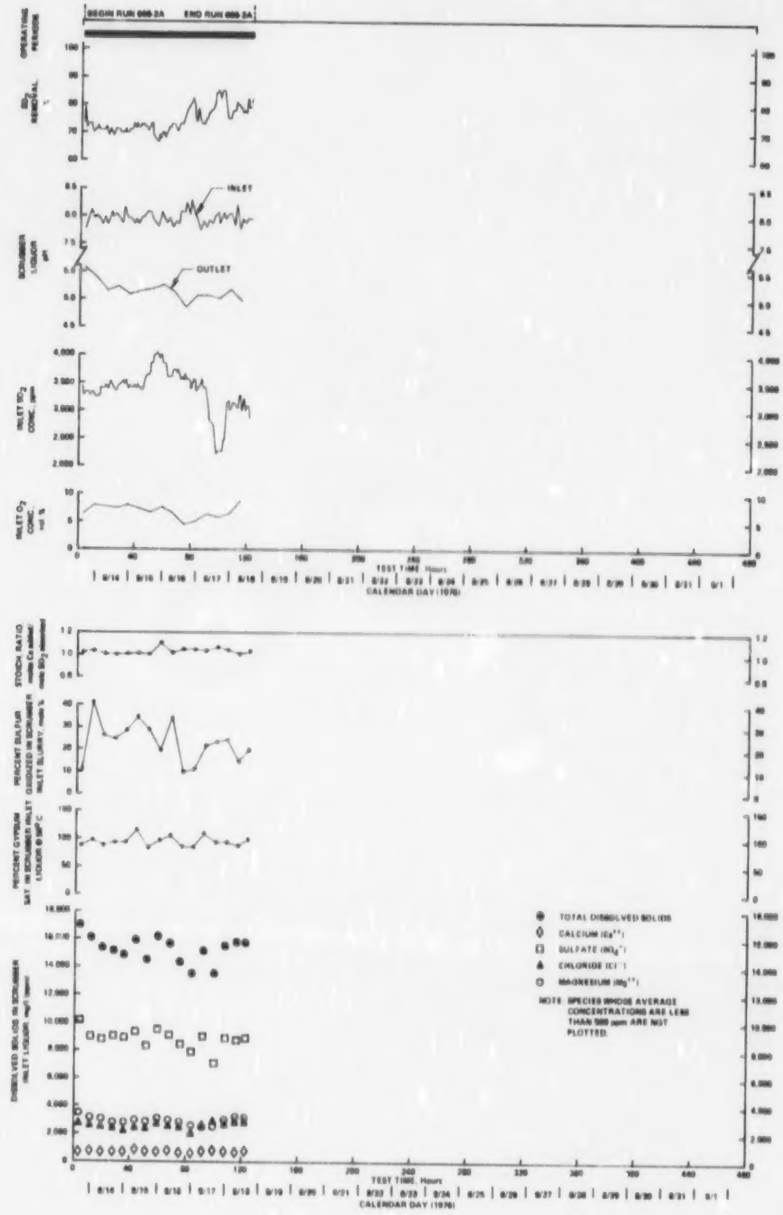
Figure I -12. OPERATING DATA FOR TCA RUN 604 - 2A



Gas Rate = 20,500 acfm @ 300° F
Gas Velocity = 8.6 ft/sec
Liquor Rate = 1200 gpm
L/G = 73 gal/mcf
EHT Residence Time = 4.1 min
3 Beds, 5 in. spheres/bed

Percent Solids Recirculated = 7-8 wt %
Total Pressure Drop, Excluding Mist Elim.
= 4.5-5.0 in. H_2O
Mist Elim. Pressure Drop = 0.25-0.32 in. H_2O
Discharge (Clarifier & Centrifuge) Solids
Concentration = 51-58 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

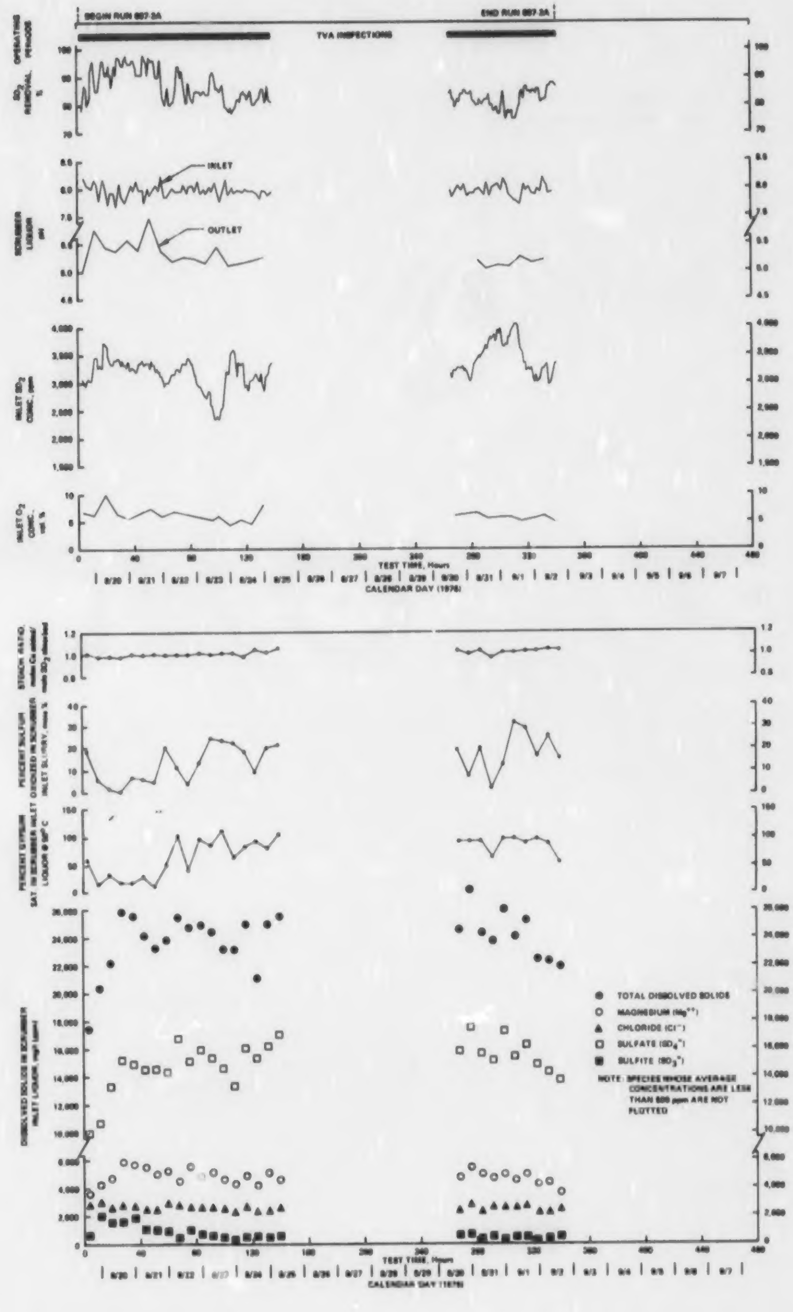
Figure I-13. OPERATING DATA FOR TCA RUN 605 - 2A



Gas Rate = 30,000 acfm @ 300° F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 900 gpm
L/G = 37 gal/mcf
EHT Residence Time = 4.1 min
3 Beds, 5 in. spheres/bed

Percent Solids Recirculated = 7.5-8.5 wt %
Total Pressure Drop, Excluding Mist Elim.
= 6.4-7.0 in. H_2O
Mist Elim. Pressure Drop = 0.51-0.56 in. H_2O
Discharge (Clarifier & Centrifuge) Solids
Concentration = 57-62 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

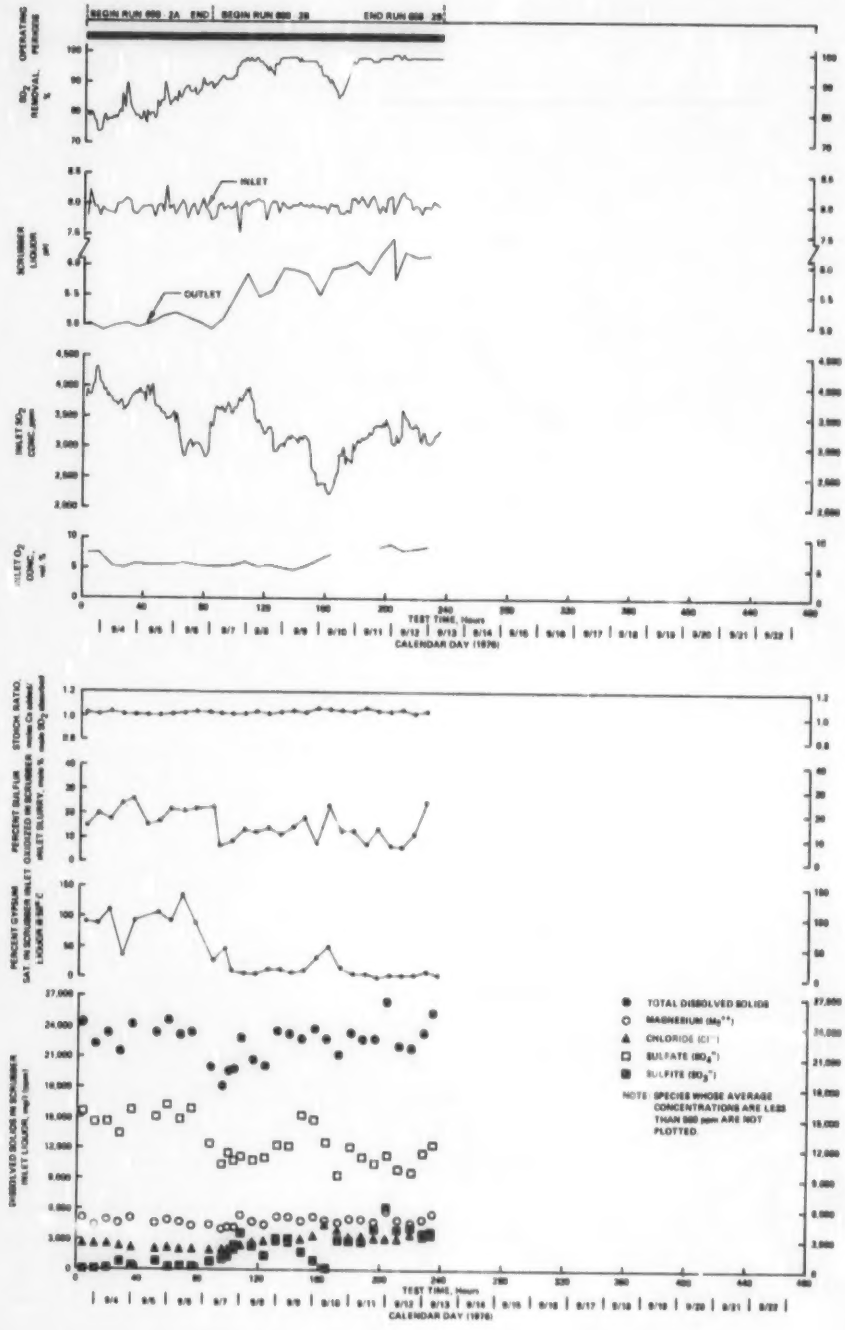
Figure 1-14. OPERATING DATA FOR TCA RUN 606 - 2A



Gas Rate = 30,000 acfm @ 300° F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 900 gpm
L/G = 37 gal/mcf
EHT Residence Time = 4.1 min
3 Beds, 5 in. spheres/bed

Percent Solids Recirculated = 7-8 wt %
Total Pressure Drop, Excluding Mist Elim.
= 5.7-7.1 in. H_2O
Mist Elim. Pressure Drop = 0.45-0.57 in. H_2O
Discharge (Clarifier & Centrifuge) Solids
Concentration = 53-58 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

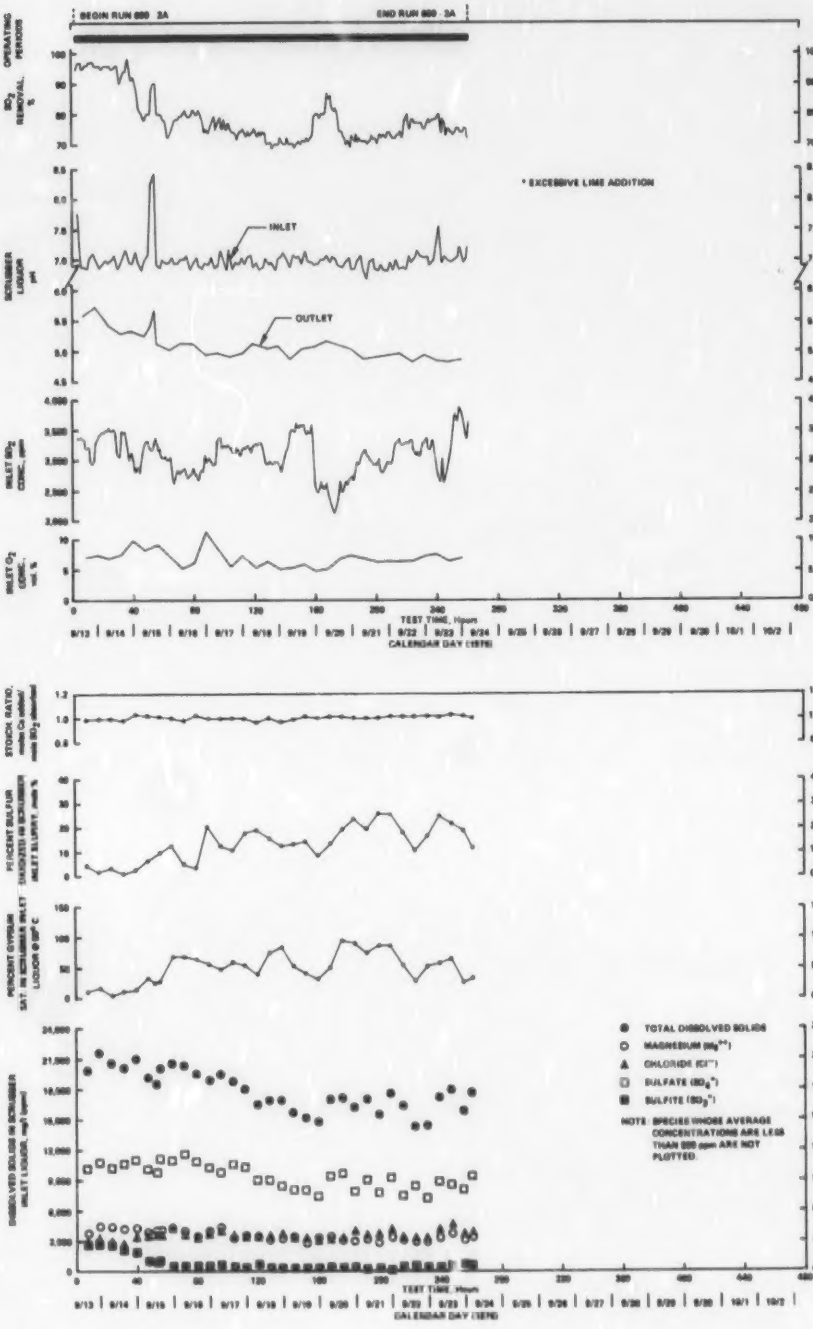
Figure I-15. OPERATING DATA FOR TCA RUN 807 - 2A



Gas Rate = 30,000 acfm @ 300° F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 900 gpm
L/G = 37 gal/mcf
EHT Residence Time = 4.1 min. (608-2A),
5.4 min. (608-2B)
3 Beds, 5 in. spheres/bed

Percent Solids Recirculated = 14.1-15.4 wt % (608-2A), 14.2-15.5 wt % (608-2B)
Total Pressure Drop, Excluding Mist Elim. = 6.8-7.6 in. H_2O (608-2A), 5.9-6.7 in. H_2O (608-2B)
Mist Elim. Pressure Drop = 0.49-0.54 in. H_2O (608-2A), 0.48-0.53 in. H_2O (608-2B)
Discharge (Clarifier & Centrifuge) Solids Concentration = 55-60 wt % (608-2A), 52-56 wt % (608-2B)
Lime Addition to Downcomer and MgO Addition to EHT

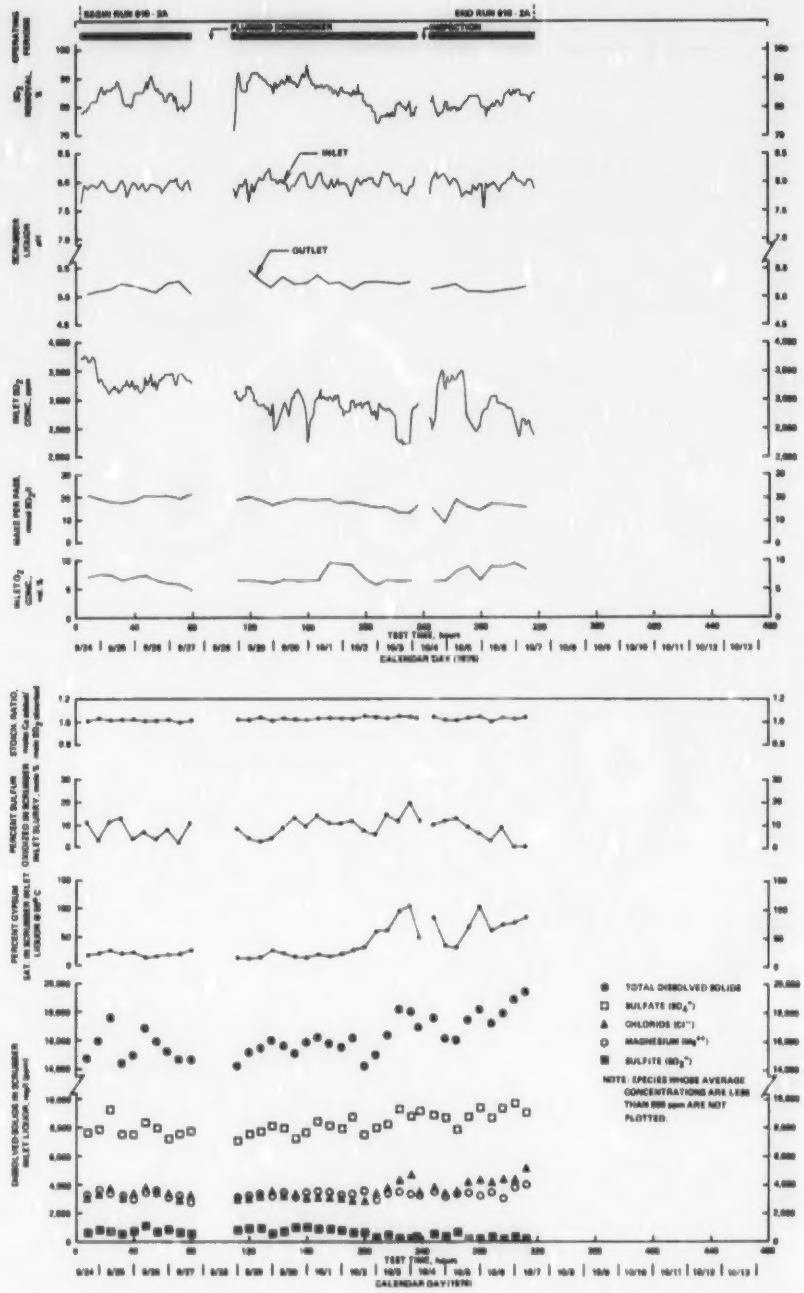
Figure I-16. OPERATING DATA FOR TCA RUNS 608 - 2A & 608 - 2B



Gas Rate = 30,000 acfm @ 300° F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 900 gpm
L/G = 37 gal/mcf
EHT Residence Time = 5.4 min
3 Beds, 5 in. spheres/bed

Percent Solids Recirculated = 7.8-8.8 wt %
Total Pressure Drop, Excluding Mist Elim.
= 5.8-6.5 in. H_2O
Mist Elim. Pressure Drop = 0.48-0.53 in. H_2O
Discharge (Clarifier & Centrifuge) Solids
Concentration = 58-63 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

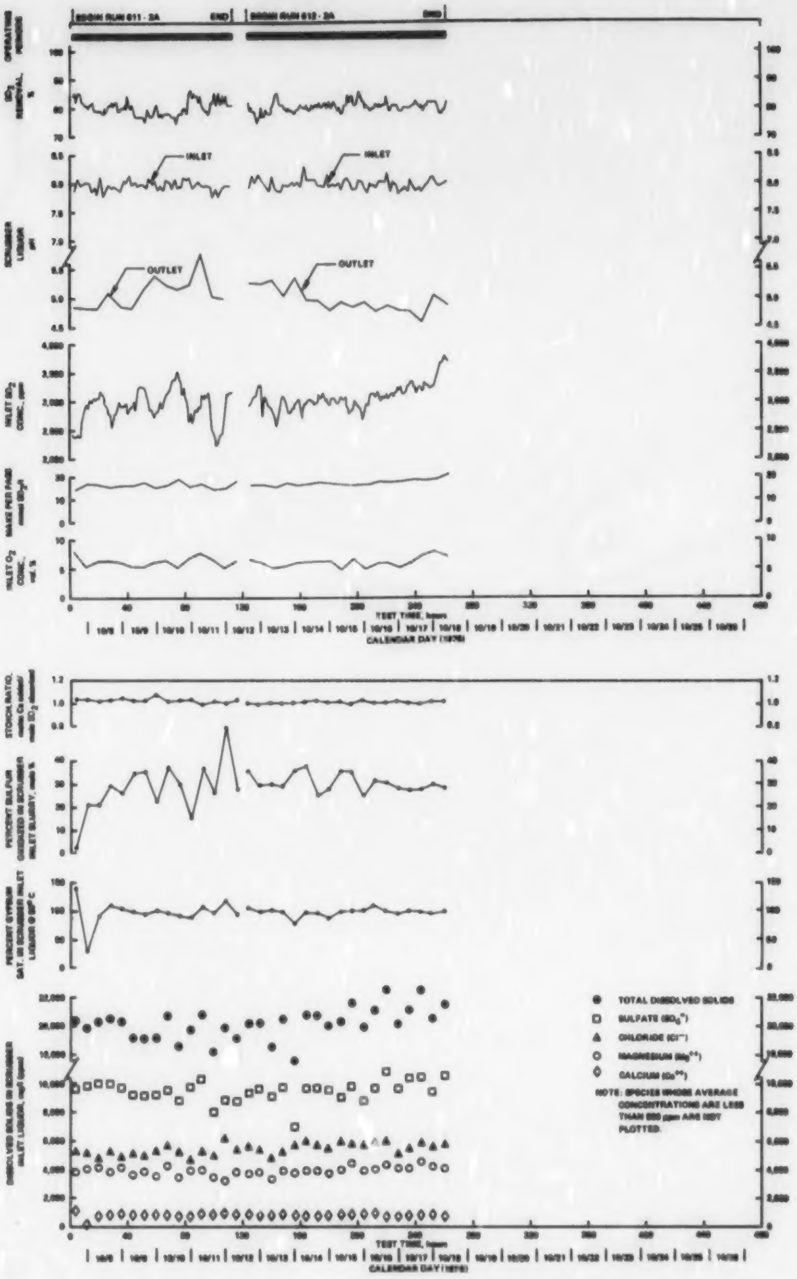
Figure I-17. OPERATING DATA FOR TCA RUN 609 - 2A



Gas Rate = 30,000 acfm @ 300° F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 900 gpm
L/G = 37 gal/mcf
EHT Residence Time = 5.4 min
3 Beds, 5 in. spheres/bed

Percent Solids Recirculated = 7.4-8.4 wt %
Total Pressure Drop, Excluding Mist Elim.
= 5.6-6.1 in. H_2O
Mist Elim. Pressure Drop = 0.47-0.53 in. H_2O
Discharge (Clarifier & Filter) Solids
Concentration = 53-67 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

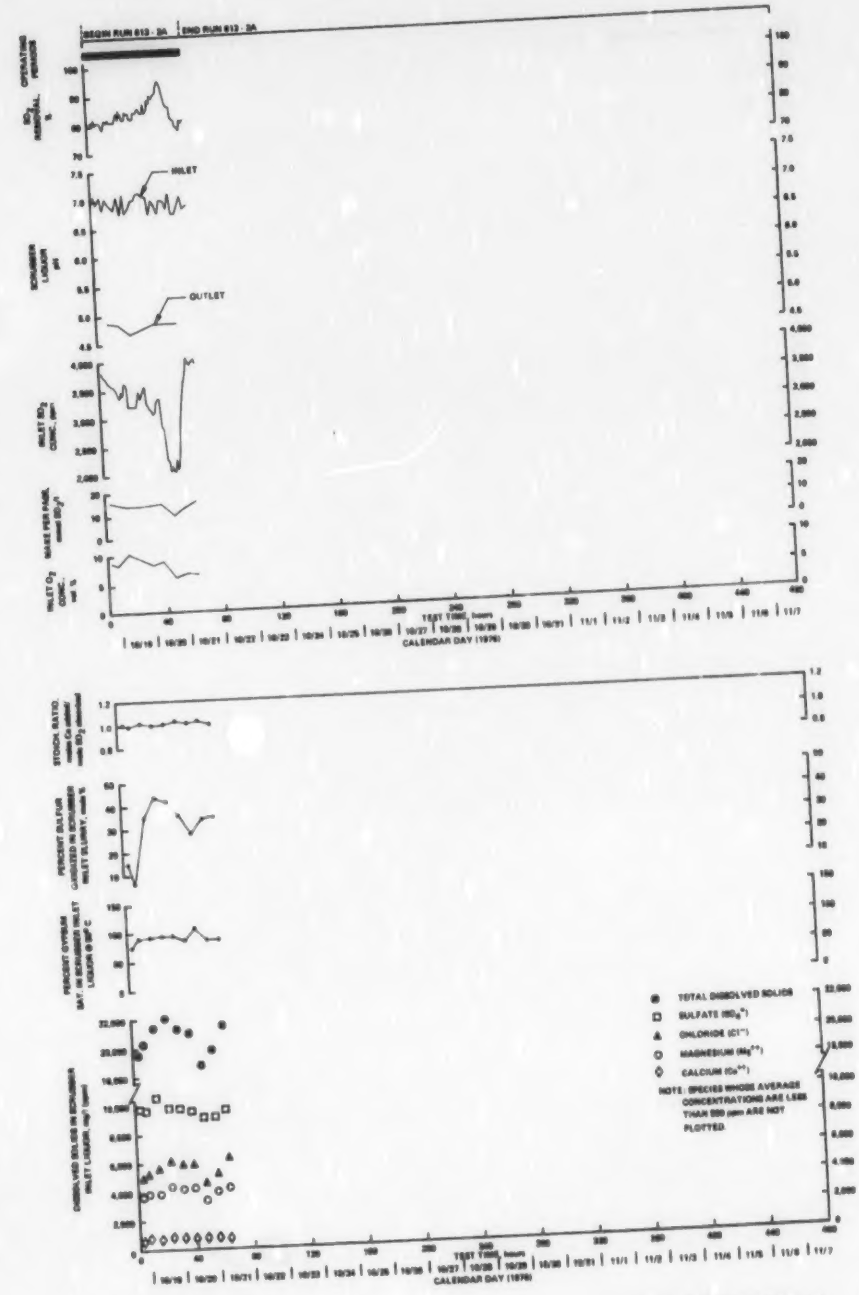
Figure I-18. OPERATING DATA FOR TCA RUN 610 - 2A



Gas Rate = 30,000 acfm @ 300° F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 900 gpm
L/G = 37 gal/mcf
EHT Residence Time = 3 min
3 beds, 5 in. spheres/bed

Percent Solids Recirculated = 7.3-8.7 wt %
(611-2A), 7.4-8.5 wt % (612-2A)
Total Pressure Drop, Excluding Mist Elim.
= 5.9-7.2 in. H_2O (611-2A), 6.4-7.9 in. H_2O (612-2A)
Mist Elim. Pressure Drop = 0.48-0.53 in. H_2O (611-2A),
0.53-0.57 in. H_2O (612-2A)
Discharge (Clarifier & Filter) Solids
Concentration = 55-65 wt % (611 - 2A)
Discharge (Clarifier & Centrifuge) Solids
Concentration = 57-61 wt % (612-2A)
Lime Addition to Downcomer
and MgO Addition to EHT

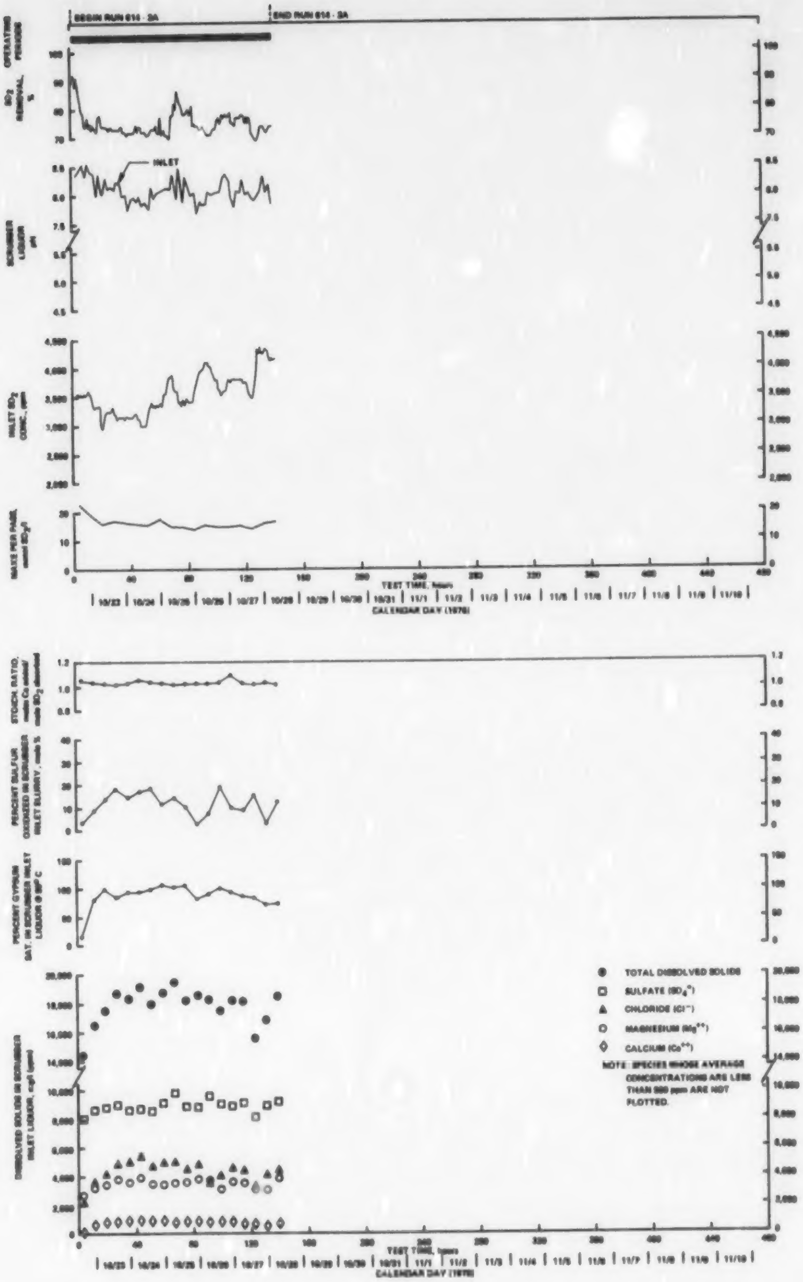
Figure I-19. OPERATING DATA FOR TCA RUNS 611-2A & 612-2A



Gas Rate = 30,000 acfm @ 300° F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 1200 gpm
L/G = 50 gal/mcf
EHT Residence Time = 3 min
3 Beds, 5 in. spheres/bed

Percent Solids Recirculated = 7.8-8.7 wt %
Total Pressure Drop, Excluding Mist Elim.
= 7.2-8.2 in. H_2O
Mist Elim. Pressure Drop = 0.57-0.61 in. H_2O
Discharge (Clarifier & Centrifuge) Solids
Concentration = 58-61 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

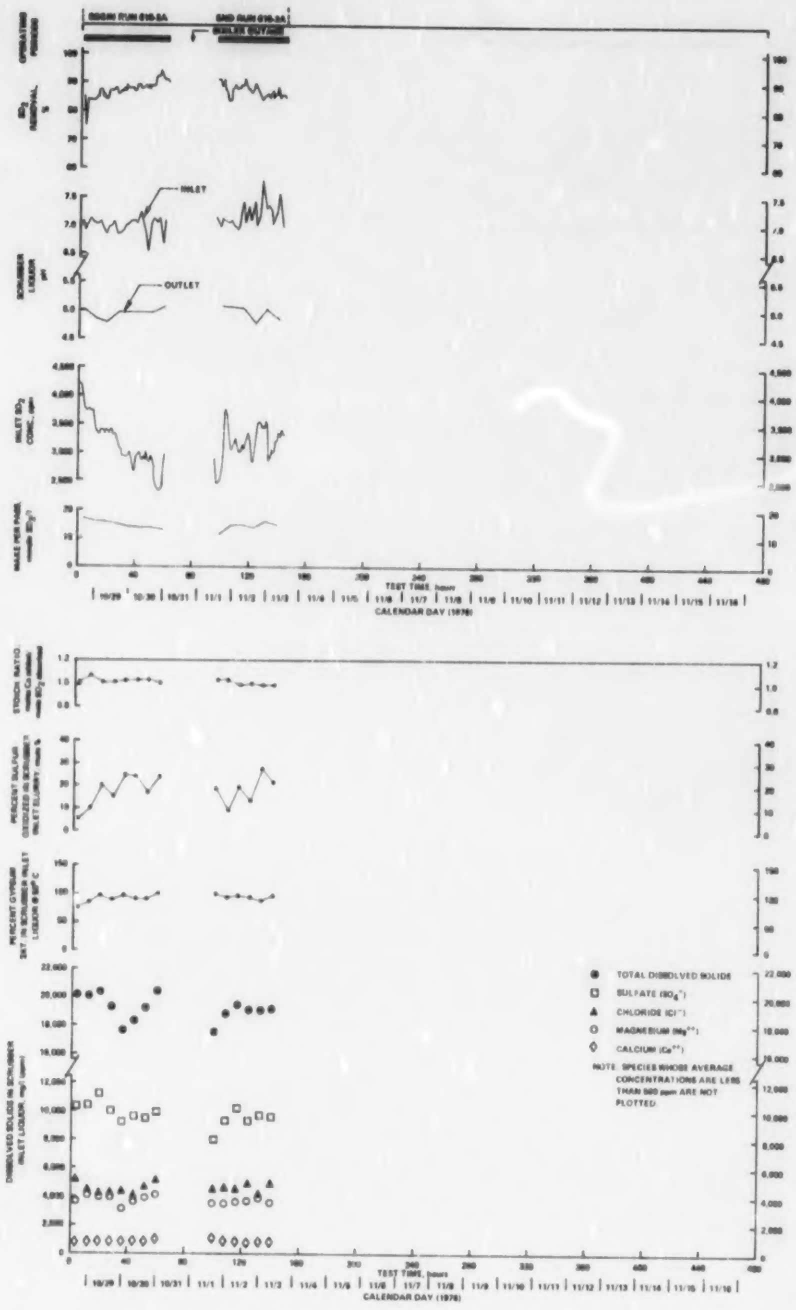
Figure I-20. OPERATING DATA FOR TCA RUN 613 - 2A



Gas Rate = 30,000 acfm @ 300° F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 900 gpm
L/G = 37 gal/mcf
EHT Residence Time = 16 min
3 Beds, 5 in. spheres/bed

Percent Solids Recirculated = 7.8-8.6 wt %
Total Pressure Drop, Excluding Mist Elim.
= 5.8-6.4 in. H_2O
Mist Elim. Pressure Drop = 0.46-0.50 in. H_2O
Discharge (Clarifier & Centrifuge) Solids
Concentration = 55-61 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

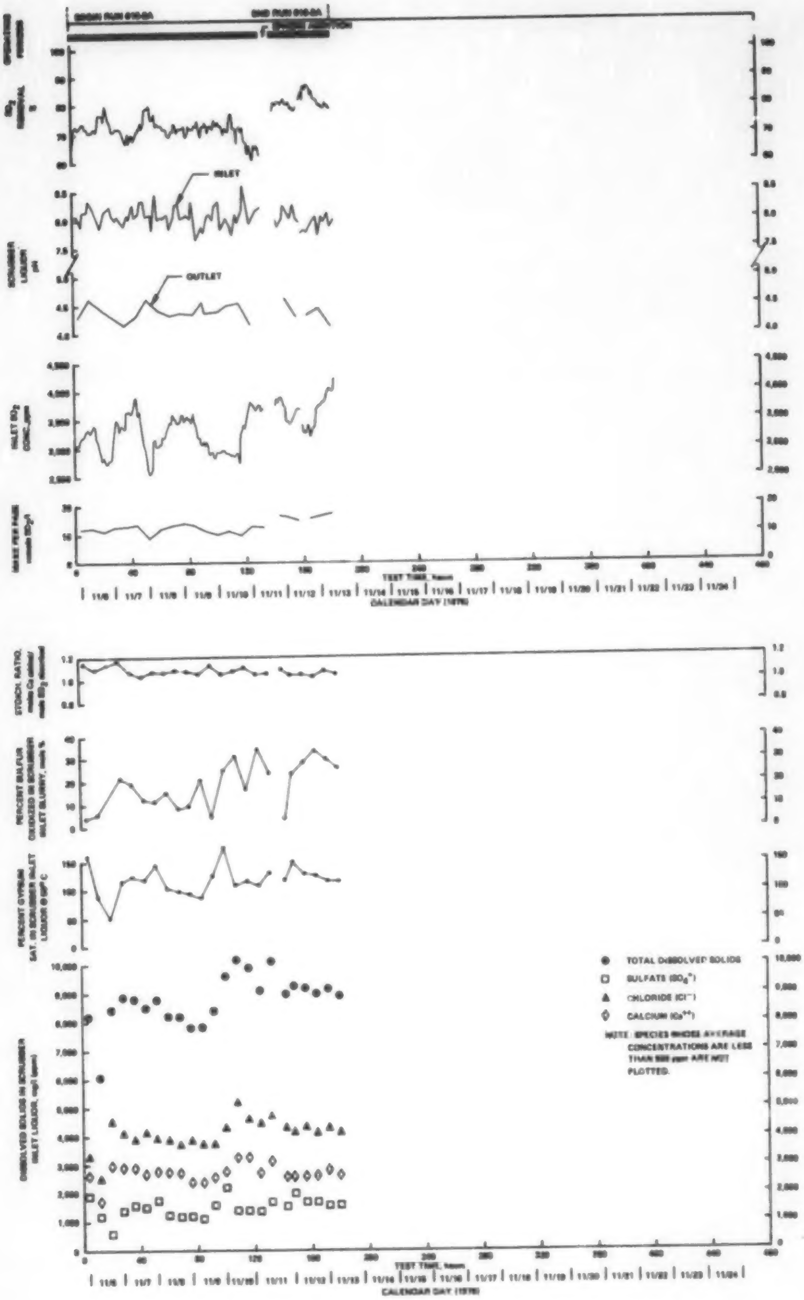
Figure I-21. OPERATING DATA FOR TCA RUN 614 - 2A



Gas Rate = 30,000 acfm @ 300° F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 1200 gpm
L/G = 50 gal/mcf
EHT Residence Time = 12 min
3 Beds, 3.8 in. spheres/bed

Percent Solids Recirculated = 7.7-8.6 wt %
Total Pressure Drop, Excluding Mist Elim.
= 7.3-8.3 in. H_2O
Mist Elim. Pressure Drop = 0.46-0.56 in. H_2O
Discharge (Clarifier & Centrifuge) Solids
Concentration = 58-67 wt %
Lime Addition to Downcomer
and MgO Addition to EHT

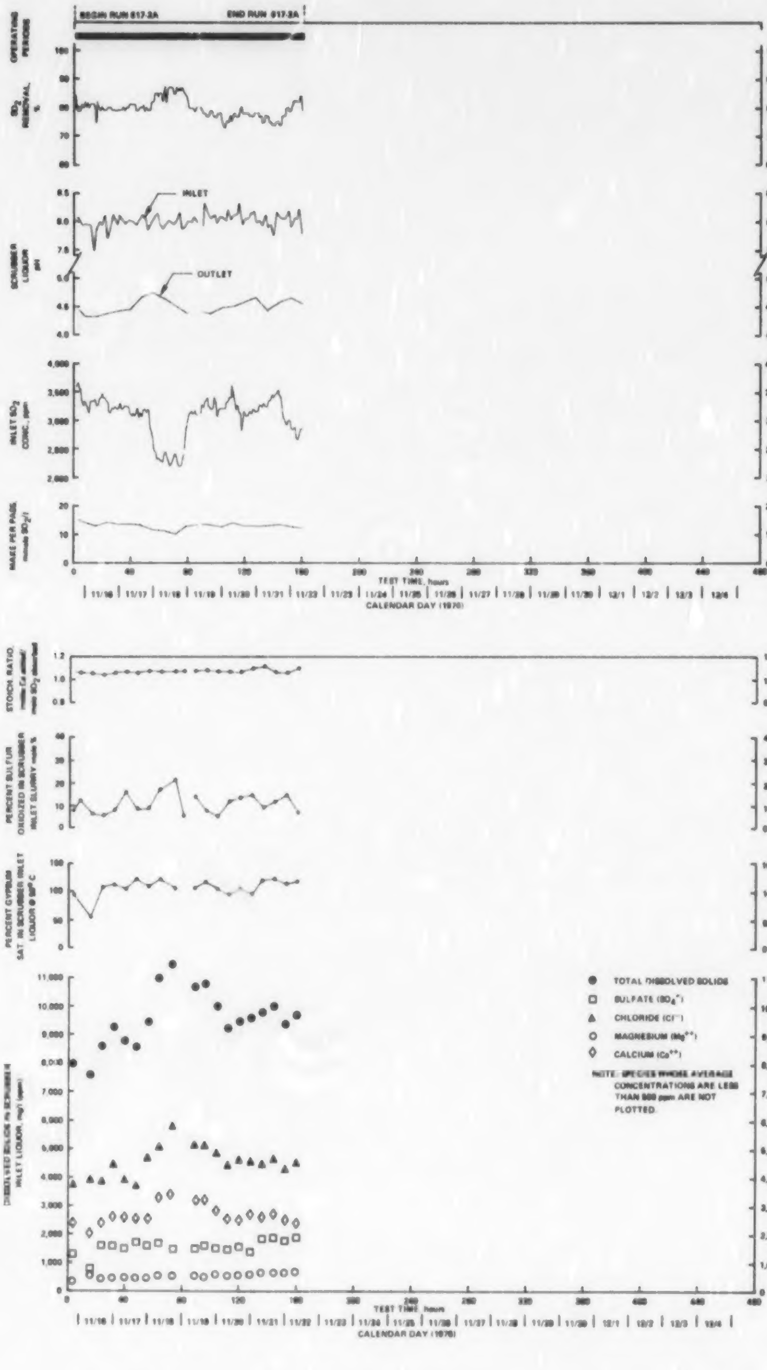
Figure I-22. OPERATING DATA FOR TCA RUN 615 - 2A



Gas Rate = 30,000 acfm @ 300° F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 1200 gpm
L/G = 50 gal/mcf
EHT Residence Time = 12 min
3 Beds, 3.7 in. spheres/bed

Percent Solids Recirculated = 7.7-8.1 wt %
Total Pressure Drop, Excluding Mist Elim.
= 6.8-8.0 in. H_2O
Mist Elim. Pressure Drop = 0.42-0.51 in. H_2O
Discharge (Clarifier & Centrifuge) Solids
Concentration = 50-63 wt %
Lime Addition to Downcomer

Figure I-23. OPERATING DATA FOR TCA RUN 616 - 2A



Gas Rate = 30,000 acfm @ 300° F
Gas Velocity = 12.5 ft/sec
Liquor Rate = 1200 gpm
L/G = 50 gal/mcf
EHT Residence Time = 12 min
3 Beds, 5 in. spheres/bed

FIGURE 1-10.

Percent Solids Recirculated = 14.0-15.5 wt %
Total Pressure Drop, Excluding Mist Elim. = 8.0-8.1 in. H_2O
Mist Elim. Pressure Drop = 0.42-0.49 in. H_2O
Discharge (Clarifier & Centrifuge) Solids Concentration = 54-60 wt %
Lime Addition to Downcomer

Figure I-24. OPERATING DATA FOR TCA RUN 617-2A

APPENDIX J

AVERAGE LIQUOR COMPOSITIONS FOR THE TCA TESTS

Table J-1

AVERAGE SCRUBBER INLET LIQUOR COMPOSITIONS FOR LIMESTONE/MgO TESTS

Run No.	Percent Solids Discharged	Percent Sulfur Oxidized	pH	Liquor Species Concentrations, mg/l (ppm)								Calculated Percent Sulfate Saturation @ 50°C[(a)]
				Ca^{++}	Mg^{++}	Na^+	K^+	$SO_3^=$	$SO_4^=$	Cl^-	Total	
583-2A	37	34	5.50	1755	2130	88	138	300	4960	8030	17400	145
583-2B	60	30	5.30	755	6480	78	118	2780	17830	3850	31890	110
584-2A	46	20	5.40	380	10900	80	90	8000	27720	5010	52180	50
585-2A	34	28	5.40	650	10590	60	70	4190	31840	4230	51630	105
586-2A	36	23	5.30	505	10070	55	65	7050	25550	4380	47680	70
587-2A	43	28	5.30	740	9720	45	60	6300	30900	2010	49780	125
588-2A	64	31	5.40	780	11300	85	60	3300	31700	6400	53630	125
589-2A	57	15	5.40	680	10400	60	85	3700	32900	3600	51430	120

Note: The values in this table are averages for the steady-state operating periods.

(a) (activity Ca^{++}) x (activity $SO_4^=$)/(solubility product at 50°C). Estimated solubility product for $CaSO_4 \cdot 2H_2O$ at 50°C is 2.2×10^{-5} (ref. Radian Corporation, "A Theoretical Description of the Limestone-Injection Wet Scrubbing Process", NAPCA Report, June 9, 1970).

Table J-2

AVERAGE SCRUBBER INLET LIQUOR COMPOSITIONS FOR LIME TESTS

Run No.	Percent Solids Discharged	Percent Solids Oxidized	pH	Liquor Species Concentrations, mg/l (ppm)								Calculated Percent Sulfate Saturation at 50°C [(a)]
				Ca^{++}	Mg^{++}	N^{+}	K^{+}	$SO_3^{=}$	$SO_4^{=}$	Cl^{-}	Total	
601-2A	57	14	7.15	390	2770	20	35	525	8650	1600	14000	50
602-2A	58	14	6.90	350	2900	25	40	425	7750	2600	14150	40
603-2A	61	20	6.90	625	3200	35	60	395	8660	3100	16150	75
604-2A	60	28	6.85	725	3150	40	70	280	8450	3090	15850	90
605-2A	55	20	6.95	370	3060	30	73	395	8130	2695	14750	45
606-2A	60	24	7.95	710	2920	23	64	265	8810	2510	15300	95
607-2A	56	15	7.90	520	4950	22	62	695	15430	2560	24250	75
608-2A	48	20	7.95	630	4800	24	67	490	15230	2260	23500	95
608-2B	54	12	7.95	120	4930	25	62	2780	11530	2980	22430	11
609-2A	59	18	6.95	490	3240	27	69	430	8580	3520	16350	60
610-2A	59	7	7.95	340	3380	29	75	670	8275	3520	16300	40
611-2A	60	30	7.95	860	3870	50	84	300	9445	5185	19800	95
612-2A	59	32	7.95	870	4055	60	95	300	9640	5600	20600	95
613-2A	60	35	6.90	835	4100	46	92	280	9810	5555	20700	95
614-2A	58	12	8.05	790	3535	43	74	345	8970	4415	18150	90
615-2A	63	17	7.05	780	3730	51	85	305	9720	4480	19160	95
616-2A	57	20	8.00	2800	200	34	115	140	1410	4160	8860	115
617-2A	57	12	8.00	2680	520	42	120	123	1560	4510	9560	110

Note: The values in this table are averages for the steady-state operating periods.

(a) (activity Ca^{++}) x (activity $SO_4^{=}$) / (solubility product at 50°C). Estimated solubility product for $CaSO_4 \cdot 2H_2O$ at at 50°C is 2.2×10^{-5} (ref. Radian Corporation "A Theoretical Description of the Limestone-Injection Wet Scrubbing Process", NAPCA Report, June 9, 1970).

Appendix K

DEFINITION OF STATISTICAL TERMS

The fraction of variation that is explained by a correlation is equal to R^2, where R is the correlation coefficient. Thus (Ref. 24, p 175):

$$\text{Fraction of Variation Explained} = R^2 = 1 - \frac{\sum (y - y')^2}{\sum (y - \bar{y})^2} \qquad \text{(K-1)}$$

where:

y = value of the independent variable for a particular data point

y' = predicted (correlation) value of the independent variable for the same data point

$\bar{y}$ = arithmetic average of all values of the independent variable in the correlated set of data

The standard error of estimate is determined from the following equation (Ref. 24, p 174):

$$\text{Standard Error of Estimate} = \sqrt{\frac{\sum (y - y')^2}{n - k - 1}} \qquad \text{(K-2)}$$

where:

n = number of data points in the correlated set of data

k = number of dependent variables fitted with coefficients

Appendix L

FOURTH TVA INTERIM REPORT OF CORROSION STUDIES: EPA ALKALI SCRUBBING TEST FACILITY

by

G. L. Crow
H. R. Horsman

April 1977

EPA ALKALI-SCRUBBING TEST FACILITY--SHAWNEE STEAM PLANT

FOURTH INTERIM REPORT OF CORROSION STUDIES

G. L. Crow and H. R. Horsman
Tennessee Valley Authority
Division of Chemical Development
Muscle Shoals, Alabama

Summary

The experimental program for removing sulfur dioxide and particulates from stack gas by lime/limestone wet-scrubbing at the coal-fired Shawnee Steam Plant is a cooperative effort of the Bechtel Corporation, EPA, and TVA. The EPA alkali-scrubbing test facility consists of three parallel scrubber systems: a venturi followed by a spray tower, a Marble Bed, and a Turbulent Contact Absorber (TCA). Each of these systems was designed to treat 30,000 acfm of gas.

The fourth series of corrosion tests conducted at the EPA alkali-scrubbing test facility located at Shawnee Steam Plant covers the period from July 19, 1975, to August 24, 1976. The first, second, and third interim reports on these corrosion studies were released in October 1973, May 1974, and March 1976, respectively. The Marble-Bed scrubber system has been idle since July 11, 1973, so this report only covers tests conducted in the TCA and venturi/spray tower scrubber systems.

Twenty alloys and five fiberglass-reinforced plastics (FRP's) were tested at various locations in the scrubber systems. Most alloys that were attacked severely in earlier tests were not tested at the same test locations or were not tested at all. Five alloys (Hastelloy G, Multimet, Nitronic 50M, Climax 18-2, and Zirconium 702) that had not been tested previously at Shawnee were included in this fourth series of tests.

Because the severity of exposure conditions varies greatly throughout the scrubber systems, the best comparative evaluation of corrosion of exposed materials is possible only if specimens of all materials are exposed simultaneously at all test locations. This practice was not continued after the first series of tests at Shawnee. Negligible corrosion thus indicates either a superior corrosion-resistant material or a very mild test environment. Negligible

corrosion for the test specimens in these tests is less than 0.05 mil per year based on weight loss. Fifteen of the alloys tested had negligible corrosion at some test locations. The following table lists these 15 alloys and lists the number of specimens of the total tested with negligible corrosion.

Alloys	Specimens with negligible[a] corrosion	
	Number	Percent
Zirconium 702	12 of 15	80
Multimet	8 of 10	80
Inconel 625	9 of 12	75
Haynes 6B	7 of 14	50
Hastelloy C-276	6 of 12	50
AL 6X	6 of 13	46
Hastelloy G	6 of 14	43
AL 29-4	5 of 12	42
Jessop 700	3 of 12	25
Nitronic 50M	4 of 18	22
Nitronic 50	2 of 9	22
Climax 18-2	2 of 12	17
Type 316L (2.8% Mo)	2 of 14	14
Type 316L (2.3% Mo)	2 of 18	11
Type 317L	1 of 9	11

[a] Less than 0.05 mil per year on basis of weight loss.

Each alloy tested was corroded to some degree at one or more test locations. Five alloys had maximum corrosion rates of 1 mil per year or less based on weight loss. Only two of these, Hastelloy C-276 and Inconel 625, were without localized attack. Crevice corrosion was noted on one specimen of Hastelloy G. Pitting occurred on one specimen of alloy Haynes 6B and crevice corrosion on two specimens. One specimen of Multimet had a pit 9 mils deep.

Another group of 10 alloys had maximum corrosion rates of 3 and 4 mils per year. Pitting and/or crevice corrosion occurred on some specimens of each alloy except for those of Zirconium 702 which showed no evidence of localized attack. The other alloys in this group are Nitronic 50, AL 29-4, Jessop 700, Type 317L, Nitronic 50M, Climax 18-2, Type 316L (2.3% Mo), AL 6X, and Type 316L (2.8% Mo).

A few tests were made of three other stainless steel alloys, Type 216, Carpenter 7-Mo, and Type 201. More tests are needed for a fair comparison of corrosion resistance with the other alloys. Cor-Ten A and mild steel, A-283, were corroded at rates that ranged from 1 to 170 mils per year.

Results of previous tests conducted in the scrubber systems show severe pitting of several stainless steels. An investigation is underway by steel producers to show the effect of molybdenum content on the resistance of alloys to localized corrosion. Data from the fourth series of tests conducted at Shawnee indicate that molybdenum content in the amount of 2.8% and 3.2% in Types 316L and 317L stainless steel, respectively, does not prevent pitting and crevice corrosion in the alkaline scrubber systems. Stock of these alloys with higher molybdenum content was not available for use in the tests. Certain combinations of other alloying elements such as chromium, nickel, and manganese produce steels that effectively inhibit localized and general corrosion. The highly alloyed material, Hastelloy C-276 and Inconel 625, were completely resistant to pitting and crevice corrosion.

Twelve specimens were tested of each of five FRP's. All specimens of Bondstrand 4000, epoxy, and those of Derakane 510, vinyl ester, were in good condition after the tests. QuaCorr, furan, had 11 good and 1 fair; Atlac 711, polyester, had 8 good and 4 fair; and Hetron 92, chlorinated polyester, had 2 fair and 10 poor.

Much of the information in this report concerning the condition of equipment in the TCA system and practically all similar information for the venturi/spray tower system was taken from reports issued by the facility inspection engineer.

The mild steel inlet flue gas duct was in good condition. The Type 316L stainless steel section of the inlet flue gas duct had deteriorated further by pitting in the zone where the incoming gas is first wetted.

The neoprene linings in tanks and in the TCA tower were in good condition; however, the lining in the flooded elbow is failing and that in the spray tower is showing signs of deterioration. A few blisters have formed in the tower lining. About 1 year ago, blisters were noted in a 4-inch neoprene-lined process slurry pipe, but they have not changed in size. Small blisters were discovered recently in another area of the neoprene-lined pipe. The condition of the neoprene lining in four pumps for the TCA system ranged from poor to excellent. The length of service could not be established for these pumps. Damage to the liners and impeller covers was attributed to circulating debris.

Exhaust stacks of Type 316L stainless steel exposed to scrubbed gases reheated to 235° to 265°F were attacked by general corrosion and pitting. Cracking continues to be a problem in the Type 316L expansion joints downstream from the induced-draft (I.D.) fan. The life of these units could be increased by solution annealing the unit after fabrication and changing the design from rectangular to cylindrical with a longer bellows, and/or use of Inconel 625 as the material of construction.

The four Type 316L stainless steel guide vanes below the adjustable plug in the venturi scrubber were worn severely. Haynes 6B is the most resistant alloy and neoprene is the most resistant nonmetal tested on the guide vanes. Pure gum rubber tubing has been used successfully to protect stay bars on spools of test specimens exposed below the venturi throat.

Plastic chevron-type mist eliminators did not prove successful because of plugging and mechanical damage. Their use was discontinued after a few hundred hours of operation. Recent improvements in maintaining cleanliness of the Type 316L stainless steel mist eliminators greatly increased the life and performance of these units.

Movement of mobile packing had eroded two flat surfaces on the 3/8-inch-diameter grid rods in the TCA scrubber tower. Thermal plastic rubber spheres and foam rubber spheres used as mobile packing have not proved entirely satisfactory. Some of the spheres penetrate between the grid rods to lower elevations.

A crack about 4 inches long occurred in the shroud of the I.D. fan in the venturi/spray tower system. It originated on the periphery of the shroud in the heat-affected zone of a weld at the same location that cracked previously. The first crack was repaired by grinding and then welding with Type 347 electrode. The second crack was repaired similarly, but the weld was made with Type 316L electrode which deposits filler metal that is more ductile.

Flakeline 103 coating was generally in good condition except in areas where it was damaged while modifications were being made in the effluent hold tanks (EHT). The epoxy-base paint applied on the bare steel shell in the damaged areas failed.

The cast steel bodies of the Hayward strainers are showing wear. The basket support ledges are deteriorating, possibly due, in part, to contact of dissimilar metals. A neoprene gasket between the stainless steel basket and the cast steel (carbon steel) body would be beneficial. The baskets are in good condition except for mechanical damage possibly inflicted during cleaning.

Two problems have been encountered with the Fabri knife-gate valves used to isolate the Hayward strainers. Solids collect in the seat and prevent complete closing of the gate. Also, the "O" ring that seals the gate was torn or cut frequently by opening and closing the gate. Recently the valves have been used without the O rings even though some leakage occurs.

Corrosion tests were made while additional magnesium oxide was used to show its effect on corrosion by the slurry. Special corrosion test specimens were installed in the scrubber slurry while 2000 to 10,000 ppm Mg^{++} was maintained in the scrubbing slurry. Normally, the Mg^{++} concentration in the scrubbing slurry is 500 to 900 ppm. These tests were of comparatively short duration. Corrosion of stainless steels was not changed appreciably by the additional MgO; however, a 2- to 5-fold increase of attack was experienced by Cor-Ten and mild steel.

The section of Type 316L stainless steel duct that extends into the chamber above the venturi failed. Metallurgical inspection revealed that failure was due to chloride stress-corrosion cracking. Also, pitting to depths of 34 mils occurred under tightly adhering scale. Laboratory tests of stressed specimens in boiling magnesium chloride solution showed Inconel alloys 600 and 625 to be the most resistant to chloride stress-corrosion cracking of several alloys tested.

EPA ALKALI-SCRUBBING TEST FACILITY--SHAWNEE STEAM PLANT

FOURTH INTERIM REPORT OF CORROSION STUDIES

Introduction

The fourth series of corrosion tests conducted at the EPA alkali-scrubbing test facility located at Shawnee Steam Plant covers the period from July 19, 1975, to August 24, 1976. The first, second, and third interim reports on these corrosion studies were released in October 1973, May 1974, and March 1976, respectively. The Marble-Bed scrubber system has been idle since July 11, 1973, so this report only covers tests conducted in the Turbulent Contact Absorber (TCA) and venturi/spray tower scrubber systems.

Program

The experimental program for removing sulfur dioxide and particulates from stack gas by lime/limestone wet-scrubbing at the coal-fired Shawnee Steam Plant is a cooperative effort of the Bechtel Corporation, EPA, and TVA. The program is funded by EPA. The Bechtel Corporation is responsible for data evaluation and technical reporting. TVA is responsible for the operation, maintenance, and modification of the facility. All three organizations participate in program planning. Identification and solution of corrosion and erosion problems associated with construction materials are important goals in a program for the design and evaluation of lime/limestone - wet-scrubbing systems. At the request of EPA in 1972, the Process Engineering Branch of TVA started corrosion tests in the scrubber systems.

Test Facility

The EPA alkali-scrubbing test facility consists of three parallel scrubber systems, but only two systems were used in the fourth series of tests: a venturi followed by a spray tower and a TCA. Each of these systems was designed to treat 30,000 acfm of gas. During the fourth series of tests, the gas contained 1500 to 4500 ppm of sulfur dioxide and 2 to 7 grains of particulates per standard cubic foot. Figures 1 and 2 are schematic diagrams of the venturi and the TCA scrubbing systems.

The scrubber systems have several features in common. An insulated 40-inch-diameter duct conveys the power plant flue gas at 320°F from the No. 10 boiler to each scrubber system. The first section of duct is made of 10-gage carbon steel, ASTM A-283; this joins a section of Type 316L stainless steel duct that contains humidification sprays and a soot blower. The shell of each scrubber tower is constructed of 1/4-inch-thick carbon steel and is lined with 1/4-inch-thick neoprene. Downstream from each scrubber, there is a stainless steel duct, a refractory-lined reheater fired with fuel oil, an induced-draft (I.D.) fan made of Type 316L stainless steel, and a stack of Type 316 stainless steel. For liquor handling there is a slurry recirculation tank, a scrubber effluent hold tank (EHT), and a liquor clarification and waste disposal system. The EHT and the clarifier tank are made of carbon steel A-283 coated inside with Flakeline 103 which is a Bisphenol polyester resin-flake glass coating manufactured by the Ceilcote Company. The recirculation tank, clarified water storage tank, and reslurry tank are made of carbon steel lined with neoprene.

There are also distinguishing features for each of the scrubber systems. In the venturi scrubber system shown in Figure 1, the gas is scrubbed in a venturi unit made of Type 316L stainless steel and then passed through a spray tower (afterscrubber) with a chevron-type separator in the top for removal of mist. In the TCA scrubber system, shown in Figure 2, gas is scrubbed in mobile beds of wetted spheres and mist is removed by a separator in the top of the tower. During previous corrosion tests, a wash tray located between the mobile beds and the mist separator in the TCA scrubber tower was used to remove some of the remaining particulate. The wash tray was removed from the system at the end of the third series of tests.

Corrosion Tests

During the fourth series of tests, specimens of 20 alloys and 5 fiberglass-reinforced plastics (FRP's) were exposed at various test locations in the scrubber systems. Periodic inspections were made of the scrubber systems and the test specimens. Personnel from the Corrosion Laboratory made a limited inspection of the TCA scrubber on March 26 and 27, 1976. The test facility engineer made reports on his inspections throughout the test period, and all the information on the venturi/spray tower system was taken from his reports.

Test Facility Operation

During much of the test period from July 19, 1975, to August 24, 1976, both scrubber systems were operated simultaneously. Operational data for the scrubber systems during the fourth series of tests are given in the following tabulation along with the accumulative operational data since each system was placed in operation.

Fourth series	Venturi/spray tower	TCA
Test period	7/23/75 - 6/14/76	7/19/75 - 8/24/76
Run No.	626-1A - 633-1A	553-2A - 607-2A
Operating hours	5999	8076
Idle hours	1849	1572
Accumulative		
Period	9/5/72 - 6/14/76	8/17/72 - 8/24/76
Hours	20,282	23,060
Days	845	961

Test Specimens

Test specimens of 20 alloys and 5 FRP's (Tables I through III) were tested in the venturi/spray tower and TCA scrubber systems at the test locations shown in Figures 1 and 2, respectively. All 20 alloys were not exposed at all test locations, and FRP specimens were only included on spool assemblies (see Fig. 3) that were exposed at test locations where temperature extremes and/or abrasive conditions were not expected to significantly affect the plastic-base materials. Specimens tested on the spool and probe assemblies shown in Figure 3 were prepared as 2-inch-diameter disks. One rack of U-shaped stressed specimens of six alloys (see Fig. 3) was exposed in the inlet cavity of the I.D. fan of each scrubber system. Wear-bar specimens of one alloy (Haynes 6B) and two types of neoprene shields were tested on the guide vanes below the adjustable plug at the venturi in the venturi/spray tower scrubber system. The composition of each of these alloys is given in Table IV.

Exposure Periods

In the venturi/spray tower system, disk-type specimens were exposed in the flue gas duct above and below the venturi. Specimens tested above the venturi and at most other test locations were exposed for 4666 operating hours from July 23, 1975, to March 24, 1976. Test data for these specimens are given in Table I. Disk-type specimens tested below the venturi (test location 1011, Fig. 1) were removed after 2370 operating hours because of the severe erosion and corrosion of the specimens. A new spool of test specimens was later installed at this test location and was exposed for 1580 operating hours, until the end of the test period. Test data for the disk-type specimens exposed below the venturi are given in Table II. The U-shaped stressed specimens exposed in the inlet cavity of the I.D. fan showed no signs of cracking during this fourth test period so this test is being continued. The wear-bar specimens showed that Haynes 6B is the most resistant alloy tested thus far. Test data for the wear-bar specimens are given in the results section along with results of similar tests conducted previously at this location.

In the TCA system, most disk-type specimens were exposed for 4990 operating hours from July 19, 1975, to March 17, 1976. One spool of specimens, which was mounted in the scrubber tower at test location 2005 (see Fig. 2), was exposed for only 2680 hours while MgO was being added to the scrubber slurry. Table III lists the test data for all disk-type specimens tested in the TCA system.

Exposure Conditions

The coal used at Shawnee Steam Plant contained 2.9 to 3.7% sulfur, 0.1 to 0.4% chlorides, and 13 to 16% ash. The compositions of inlet and outlet gas at the scrubber systems were as follows:

Component	Stack gas[a]	Scrubbed gas
SO_2, %	0.2-0.4	0.02-0.10
CO_2, %	10-18	11-19
O_2, %	5-15	6-16
H_2O, %	8-15	9-16
HCl, %	0.01	-
N_2, %	74±	69±
Fly ash, gr/stdft^3	2-7	0.01-0.04

[a] Taken from unit 10 ahead of mechanical dust collectors.

The temperature of the inlet stack gas was in the range of 260° to 330°F and that of the exhaust gas after being reheated was 235° to 265°F.

Properties of liquor in the effluent and clarifier tanks of the two scrubber systems are given in Tables I and III.

Table V shows analyses of deposits removed from the venturi and the TCA scrubber systems.

Preparation and Mounting of Specimens

Preparation

Disk-type specimens of alloys and FRP's were 2 inches in diameter and had a 23/64-inch hole drilled through the center for assembly on a spool-type or probe-type mount (see Fig. 3). Teflon insulators were used to prevent contact of dissimilar metals. Disk-type specimens of the five FRP's were made from sheets about 1/8-inch thick, and the machined edges of the disks were sealed with resin as recommended by the manufacturers. Disk-type specimens of the 20 alloys tested were made from metal stock about 1/8 inch thick that had been welded according to the recommendations of the manufacturer of the respective alloy. After these welds were made, the alloys were allowed to cool slowly in air to simulate cooling of large equipment after it has been welded during construction or repair. After the alloys were welded and cooled, the 2-inch-diameter disks were prepared so that the weld was across the diameter of the disk. The disks were smoothed either by machining or, in cases where the disk was less than 1/8-inch thick, by grinding.

Stressed specimens were made by forming a strip of alloy (about 1/8 by 1 by 5-1/2 inch) into a U shape and drilling a 1/2-inch hole in each end of the strip to accommodate a 1/4-inch bolt (Type 316 stainless steel). This bolt, which was fitted with a Teflon insulator, was used to apply static stress to the specimen in a rack as shown in Figure 3.

Wear-bar specimens consisted of a rod (1/4 by 1/4 inch with all surfaces ground smooth) supplied by the manufacturer and two types of neoprene shield (a 1-inch-diameter pneumatic hose and a 1/4-inch-thick multilayered sheet).

Mounting

Disk-type specimens were mounted in the scrubber systems by one of four methods. At some test locations, spool assemblies were bolted to permanent brackets that had been welded in place. In other test locations, spool assemblies were bolted to an existing pipe by means of a band-type clamp (see Fig. 3). In tanks, spools were suspended by a 1/8-inch strip or a 3-inch-diameter pipe bolted to the top of the tank. Sleeves of soft butyl rubber (3/8 inch thick and 6 inches long) were used on these support pipes to prevent abrasive damage to the Flakeline coating or neoprene lining of the tank walls. In vessels or ducts, probe-type assemblies were installed through the wall by means of a 2-inch pipe coupling and companion plug that supported the assembly.

Stressed specimens were installed by bolting the rack (see Fig. 3) to a bracket that had been welded at the desired location. The wear-bar specimen of alloy Haynes 6B was installed by clamping both ends directly to a specimen holder placed on one of each of four sliding guides downstream from the venturi throat. The specimen was not insulated from the Type 316 stainless steel specimen holder. Specimens of neoprene, which were placed over sections of stainless steel pipe adapted to sit on the sliding guides, were fastened by means of hose clamps or stainless steel bolts.

Results of Plant Inspections and Corrosion Tests

During the fourth series of tests, periodic inspections were made of the scrubber systems and the test specimens were observed. All corrosion rates were calculated on the basis of weight loss (if any) of specimens assuming that the loss occurred during the period of operation of the scrubber system rather than during the overall exposure period. In the first and second interim reports, a corrosion rate was determined on the basis of weight loss (negligible if very little or no weight loss was found), regardless of whether localized corrosion occurred. However, in the third and current interim reports, low corrosion rates determined by weight loss are omitted for test specimens that had significant penetration by crevice corrosion and/or pitting.

Durometer A hardness values of rubber lining on equipment were measured with a Shore instrument, Type A2, ASTM 2240. Unfortunately, hardness of lined plant equipment was not determined at Shawnee before the plants were operated, so data from the rubber vendors were used as reference values.

Inlet Ducts for Flue Gas

The flue gas contains flyash, carbon dioxide, oxygen, moisture, nitrogen, hydrogen chloride, and sulfur dioxide at temperatures of 260° to 330°F.

Carbon Steel Ducts: The carbon steel inlet gas ducts are in good condition. A thin rust-colored scale was observed in some areas. A sample of similar scale taken from inside one of the ducts near a joint during an earlier test was analyzed and its chemical composition is given in the following tabulation.

Composition, %					
Mg as MgO	SO_3 as $CaSO_4$	SO_2 as $CaSO_3$	CO_2 as $CaCO_3$	Cl as $CaCl_2$	Acid insoluble
0.31	33.19	1.18	1.72	0.24	58.59

Also, small quantities of flyash were deposited in the ducts where the gas flow changes directions, but this caused no apparent problem.

Stainless Steel Ducts: A Type 316L stainless steel section of inlet gas duct is located between the carbon steel section of duct and the scrubber unit of each system. In the TCA system, humidification sprays are located in the stainless steel section of the duct. These sprays were used continuously during original operation of the unit. Now they are used for emergency cooling with slurry to prevent overheating of the neoprene lining in the tower in the event that flow is lost in the slurry cooling sprays downstream. The emergency sprays are activated from the control room. Spray nozzles in the emergency unit become plugged and require cleaning occasionally. Pits that formed in this area of the duct under deposits of solids during earlier tests, when the humidification sprays were used continuously, increased little (if any) in dimensions while the sprays were idle.

The soot blower for the TCA system was in good condition and was performing satisfactorily on an operating schedule of blowing once per day to clean the duct. The stainless steel duct in the immediate area of the soot blower showed little erosion or corrosion. However, the walls of the duct near the entrance to the scrubber tower (slightly downstream from the slurry cooling sprays) were pitted to depths of 75 mils. This is the area where the first wetting of the flue gas occurs. The cooling sprays consisted of three Type 316L stainless steel nozzles. These were 90-degree, full-cone, spiral-type Bete fog nozzles (ST 24FCN).

The life expectancy of a Type 316 stainless steel diffuser is about 3000 hours. Nozzles of Stellite are superior in wear resistance to those of Type 316 stainless steel for this service. A Stellite diffuser was in excellent condition after it had been used to spray limestone slurry for 2500 hours. The stainless steel support rod for the coiled temperature sensor probe (TE-2007) located downstream from the sprays was pitted moderately. This new support rod was installed after the third series of corrosion tests was completed.

Specimens Tested in Inlet Gas Ducts: The hot inlet flue gas to the scrubber systems is not severely corrosive. However, when its temperature is reduced, the moisture present condenses and becomes corrosive to some alloys. Since the use of humidification sprays in the inlet flue gas ducts has been eliminated except for emergency cooling, less corrosion of specimens has occurred at test locations 1002 and 2002. These sprays were used in the first series of corrosion tests, and the rates for Cor-Ten and mild steel at test location 1002 in the venturi system (see Fig. 1) were greater than 290 and 330 mils per year, respectively. In the fourth series of tests, the corrosion rates for similar alloys at location 1002 were 42 and 28 mils per year, respectively (refer to Table I). The rates were 3 mils per year for the same alloys at test location 2002 in the TCA system (see Fig. 2 and Table III). The maximum corrosion rate was 5 mils per year for the other alloys tested at location 1002 during the fourth series of tests and less than 1 for alloys tested at location 2002.

Venturi Unit

Shell and Bull Nozzle: The Type 316L shell of the venturi section required occasional repairs. Joints were rewelded and larger holes were patched with stainless steel sheet. The second 5-inch-diameter bull nozzle failed, and the original nozzle that already had been used 265 operating days was repaired and reinstalled for a second period of service. Four inches was cut from the discharge end of the nozzle to permit full travel of the venturi plug.

Chloride Stress-Corrosion Cracking: A section of Type 316L stainless steel inlet flue gas duct extends about 7 inches inside the chamber immediately above the venturi. The duct is 40 inches in diameter and is constructed of 3/16-inch-thick plate. Failure occurred to the section that extended through the wall into the chamber.

Figure 4 shows a section of the duct that failed and dropped to a position under the adjustable plug which regulates the velocity of the gas-slurry mixture through the venturi. This section was 7 inches wide and 26 inches long.

Failure of the Type 316L stainless steel duct was due to embrittlement caused by stress-corrosion cracking. Examination of the metal using a microscope revealed many cracks. These cracks originated on the outside surface of the duct and some of them penetrated the wall. The stresses were mainly residual produced by cold forming and welding; however, cyclic stresses produced by vibrating equipment could have added to the severity.

The outside surface of the section that failed contained a tightly adhering scale approximately 50 mils thick that was difficult to remove. Also, pitting to depths of 34 mils occurred under the scale (see Fig. 4). The scale contained 0.85% by weight of Cl as calcium chloride. A complete analysis of the scale is given in Table V (1/9/76, VD-1).

The temperature of the inlet gas ranges from 260° to 330°F. Splashing of the process lime/limestone slurry occurs as it is discharged from the bull nozzle onto the adjustable plug causing deposition of wet solids on the external surface of the duct section that extends inside the cavity. The process lime slurry contains 400 to 8400 ppm of chloride ions. The high temperature of the duct wall evaporates moisture from the deposited solids and thus concentrates chlorides on the Type 316L duct.

Figure 5 is a photomicrograph that shows chloride stress cracks in the duct wall (magnification 50X). This shows that the cracks originated on the outside surface which was in tension. These cracks are both intergranular and transgranular. In Figure 6, boundary lines of crystals can be seen vaguely at 500X. Sensitization was not observed in any specimen examined and did not contribute to embrittlement of the metal. If the metal were sensitized, the grain boundaries would be prominent.

Laboratory Tests: Laboratory tests were made to identify alloys that are more resistant to chloride stress cracking than Type 316L stainless steel. Type 316L stainless steel was included in the tests to verify the type of failure that occurred in the flue gas duct and to establish its endurance for comparison with other alloys under laboratory test conditions. The test procedure was in fair agreement with ASTM Designation G 36 - 73 which is a standard practice for performing stress-corrosion cracking tests in boiling (295°F) magnesium chloride solution (42% by weight). Strips 1 inch wide were cut from 1/8-inch-thick sheets and formed to make U-bend stress specimens for use in the tests. The tabulation below shows the alloys tested and the exposure period that elapsed before the first crack was noted.

Alloy	Days to failure
Type 316L	1.4
Incoloy 800	1.6
Nitronic 50	3
Carpenter 20Cb-3	3
AL 6X	8
Incoloy 825	9
Jessop 700	12
Inconel 600	55[a]
Inconel 625	55[a]
Inconel 625, welded	55[a]

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[a] No failure.

Inconel alloys 600 and 625 were by far the most resistant alloys evaluated in the laboratory tests. Specimens of these alloys showed no cracks after 55 days of exposure.

Figure 7 is a photomicrograph (50X) of a section from the U-bend Type 316L stressed specimen that cracked in boiling magnesium chloride solution in 34 hours. The cracks in the failed duct, shown in Figure 5, are the same type as those in the broken U-bend specimen.

It appears that this problem could be solved by removing the section of Type 316L duct that extends inside the cavity. However, if this section is essential to performance of the unit, the Type 316L duct should be replaced with a section of either Inconel 600 or 625 duct.

Guide Vanes: The severe erosion-corrosion of the guide vanes located immediately below the venturi, which is caused by high velocity of the gas-slurry mixture leaving the venturi, continued during the fourth series of tests. Occasionally the guide vanes have required minor repair such as replacing worn bolts. Extensive wear, pitting, and general corrosion will necessitate frequent patching or replacing of vital parts. Some protection for these units has been provided by installing test specimens on top of the vanes. The specimens were in the form of wear bars, sections of stainless steel pipe, and neoprene shields.

Table VII lists all the materials that have been tested to date on the guide vanes and gives their exposure location, duration of the tests, and gives the results. Erosion-corrosion is more severe on the north and east vanes than on the south and west vanes. The difference in severity has been attributed to channeling of the flue gas - lime/limestone slurry mixture. Alloy Haynes 6B was the most resistant of the metals tested. A 1/8-inch-thick wear bar of alloy Haynes 6B had a rate of 162 mils per year with pitting on the sheared edges. A 1/4-inch-thick specimen with all surfaces ground smooth had a rate of 370 mils per year, but no pitting occurred. Pitting of the 1/8-inch-thick specimen was attributed to severe cold working of the edges by shearing. The other alloys tested were Type 316 stainless steel, Nitronic 50, Inconel 625, and Type 201 stainless steel. The erosion-corrosion rates for these alloys ranged from 0.5 to about 5 inches per year. Neoprene was tested in two forms as shields for the guides. One form was a 1-inch-diameter pneumatic hose with a 2-braid, 1/4-inch-thick wall, and the other was a 1/4-inch-thick multilayered sheet. The neoprene sheet remained in service longer than the hose, but the specimens of sheet were exposed to the least severe conditions (on the south and west guide vanes).

Specimens Tested Below the Venturi: The specimens were installed directly below the venturi at test location 1011 shown in Figure 1. The test conditions and the results are given in Table II. Exposure conditions were more severe at test location 1011 than at any other location where disk-type specimens were tested in the two scrubber systems. Because of the high erosion-corrosion rate, some specimens on the spool had failed after 2370 operating hours. The first spool was replaced by another spool of identical makeup. The second spool remained in the system for 1580 operating hours before the fourth series of tests was concluded.

Because the two spools of specimens were identical and were mounted on the same bracket during exposure, it is obvious from the tabulated data that the second spool was mounted 180 degrees from the way the first spool was mounted. Channeling of the gas-slurry mixture caused greater erosion-corrosion on one end of the spools than on the other. The most promising alloys in the order of decreasing resistance were Haynes 6B, Type 317L, AL 29-4, AL 6X, and Zirconium 702. Pitting and/or crevice corrosion occurred on specimens of a few alloys. The specimens of Cor-Ten A and mild steel A-285, which were completely destroyed, had corrosion rates greater than 1855 mils per year. These materials also failed in previous tests at this location.

The specimens exposed at location 1011 remained clean throughout the tests. The four spacer rods on each spool used in previous series and in the first test of this series were eroded severely and had to be replaced. Rubber tubing (pure gum) was used to cover the spacer rods on the second spool used in the current series. After the 1580-hour exposure period, the rubber shield was in good condition and it had protected the spacer rods. In the future, spools to be mounted at test location 1011 will have the spacer rods protected with rubber tubing.

Flooded Elbow: Adhesion losses caused sagging of the neoprene lining from the carbon steel shell in the flooded elbow. Repairs were made by replacing small sections of the lining or by splitting the sagging section, cleaning the metal surface, and applying new adhesive. Epoxylite, an epoxy-base material, was used also to cover small areas of bare metal shell. The formation of blisters in the flooded elbow occurred more frequently during the fourth series of tests than during previous tests. This probably resulted from overheating during momentary loss of spray to the venturi before the humidification sprays upstream were activated to cool the inlet flue gas.

Scrubber Towers

Neoprene Lining: The neoprene lining on the walls of the TCA scrubber tower appeared to be in good condition. No change of importance had occurred since the last inspection prior to the third interim report. Impingement of slurry from sprays and from TCA spheres have caused minute erosion of the lining in a few areas. Slight mechanical damage, possibly due to impact by equipment and/or tools when changing the internal components, has occurred in a few areas mainly in or near doorways. Table VI gives the test location, original and current Durometer A2 hardness values, and temperature at the time tests were made. Durometer A hardness values of rubber lining on equipment were measured with a Shore instrument, Type A2, ASTM 2240. Unfortunately, hardness of lined plant equipment was not determined at Shawnee before the plants were operated, so data from the rubber vendors were used as reference values. The original Durometer A hardness (taken from the vendor's data) of the neoprene liners was 60 to 65 at 73°F (ASTM Standard D2240-68). The current range of hardness values of the lining in the TCA tower was 39 to 49. All measurements were not taken at the same temperature (range was 74°-90°F) because of the changes in the weather. As the temperature increases, the hardness values decrease.

The venturi/spray tower developed a few blisters in the neoprene lining above the mist eliminator. These were first noted January 26, 1976. The system had been in service about 3-1/2 years (741 operating days). Figure 8 shows an undisturbed blister and another from which the fluid had been drained. These were less than an inch in diameter. The 1/4-inch-thick neoprene sheet consists of several layers. Fluid collected between the first and second layers to form the blister and did not penetrate to the carbon steel shell (see Fig. 8). Straw-colored liquid withdrawn from the blister had a pH of 2.3. The analysis of the liquid in ppm follows: calcium, 200; magnesium, 5850; sodium, 300; potassium, 200; sulfite, 6550; sulfate, 51,050, and chloride, 5900. The low pH and high sulfate content indicate the liquid contains sulfuric acid. Only slight wear in small areas by impingement of slurry from sprays is noticeable on the neoprene lining.

Grids: Four grids are used in the TCA scrubber tower. Three of these support spheres in most runs; the fourth (top) grid prevents the spheres from being drawn up the duct by the I.D. fan. The grids in current use are made of 3/8-inch-diameter rods of Type 316 stainless steel. They were installed in October 1973 and had been in service about 17,000 operating hours as of August 1976. Pitting occurred on the Type 316 stainless steel grid supports and on the grid rods. Crevice corrosion was prominent where the rubber grommets contacted the rods on the ends. Movement of the TCA spheres caused wear of the rods that supported them. The wear occurred in two planes on the top half of the grid rods. The diameter of the rods, as measured on the flat surfaces, had decreased 12 to 27 mils since installation.

Spheres: Thermal plastic rubber (TPR) spheres were used in the TCA absorber during the first part of the fourth test period. After 1960 hours of service, the spheres had lost 5 to 9% in weight and after 3270 hours, the loss was as much as 12% for some spheres. After considerable wear of the surface, many of them either split in half at the mold seam or dimpled, which permitted them to squeeze through the space between the grid bars. This caused blockage of strainers in the slurry lines. The TPR spheres were removed from the system after 3800 hours of service.

Acrylonitrile foam spheres (trade name, Paracryl; Uniroyal Company), manufactured by the Pawling Rubber Company, were installed in the TCA scrubber tower December 19, 1975. As of August 1976, the Paracryl spheres had given fairly good service except that some of the spheres lodge in an escape through the space between the grid rods.

Apparently, the impact of moving spheres forces some of them through the grid opening. When the spheres were new, their diameter was 1.625 inches (nominal). After 1440 hours of service, the diameter was 1.37 inches or about 85% of the original. Measurements made after 1820 hours of operation showed no further shrinkage, and loss in weight was 4 to 5.6%. The spheres had been in service 3060 hours as of August 12, 1976 (run 605-2A).

Wash Tray: The Koch (wash) tray was removed from the TCA tower during the outage in May 1975 before the fourth series of corrosion tests was started.

Mist Eliminators: A two-stage FRP mist eliminator was installed in the TCA tower before run 546-2A which started June 8, 1975. Each stage was a three-pass, closed-vane, chevron-type unit. The lower stage was provided with undersprays and oversprays. The FRP unit was removed from service after 750 operating hours at the end of run 552-2A (July 14, 1975). The lower stage was plugged and the upper stage had been damaged by falling solids that had accumulated on the walls of the duct above.

A chevron-type, open-vane, three-pass mist eliminator of Type 316L stainless steel was installed in the TCA tower at the beginning of run 553-2A (July 19, 1975). As of August 1976, the unit had been used 7330 operating hours and appeared to be in good condition. Previous reports have stated that pitting and crevice corrosion of stainless steels in the scrubber systems occur most frequently under deposits of scale and mud. The installation of automatic spray systems for improving cleanliness of the Type 316L mist eliminators has increased the life and performance of the units.

The mist eliminator in the afterscrubber of the venturi system is also a chevron-type, open-vane, three-pass unit of Type 316L stainless steel. It was installed before run 622-1A (January 30, 1975) at an elevation 1 foot above that of the previous unit. The unit could not be inspected August 26, 1976, because run 639-1A was in progress. The mist eliminator had been in service about 10,000 operating hours.

Spray Nozzles: The process slurry is fed to the TCA tower through four 1969F Spraco nozzles (full-cone, free-flowing) of Type 316 stainless steel which are located in quadrants above the fourth (top) grid. New nozzles were installed September 19, 1974, and they had been in service approximately 12,000 operating hours as of

August 26, 1976. One nozzle was plugged with solids and the swirl vanes in each nozzle were grooved. The diameter of the discharge throat increased 31 to 46 mils during this period of service. In general, these Spraco nozzles have given good service.

The spray tower of the venturi scrubber system has four levels of slurry sprays. Also, the mist eliminator has an underspray and an overspray consisting of several nozzles that spray makeup water and/or clarified water. Bete nozzles with Stellite diffusers give better service than those with Type 316 diffusers when the slurry contains flyash. The diffusers are now being tested while scrubbing flue gas that is essentially flyash free.

Specimens Tested in Towers: The locations of test specimens in the venturi spray tower are shown in Figure 1 and those for the TCA scrubber tower are shown in Figure 2. The test conditions and corrosion rates are given in Tables I and III, respectively. Results for the short-term corrosion tests conducted while magnesium oxide was being added to the slurry are included in the same tables. Footnotes in the tables identify tests made while magnesium oxide was being used. The exposure media, test locations, and the amount of solids on the spools when the tests were completed were as follows:

Scrubber system	Test location No.	Test medium	Amount of solids on spool
Venturi	1006	Gas and liquor	95% covered
	1005	Gas and liquor	80% covered
	1004	Gas and droplets	100% covered
TCA	2006	Gas and liquor	None (clean)
	2005	Gas and droplets	90% covered
	2004	Gas and mist	80% covered

Corrosion was negligible to 1 mil per year in the tower of both scrubber systems for the following alloys: Hastelloy alloys C-276 and G, Haynes 6B, Inconel 625, Jessop 700, Multimet, and Zirconium 702. The following alloys lost little weight but experienced localized attack in one or both towers: AL 6X, AL 29-4, Climax 18-2, Nitronic 50, Nitronic 50M, and stainless steel Types 316L and 317L. Cor-Ten A had the greatest corrosion rates of all materials tested (mild steel was not tested). At test locations from the bottom upward, the respective corrosion rates were greater than 108, 21, and 9 mils per year in the spray tower and were 42, 26, and 19 mils per year in the TCA tower. Contrary to the results for the second series of tests, data for the fourth series of tests show that conditions were least severe in the top of the tower. Perhaps the oversprays and undersprays currently used on the mist eliminators decreased the severity of corrosion of test specimens at the upper test locations.

Five plastic-base materials were tested at three locations in each scrubber tower. Bondstrand 4000, an epoxy, and Derakane 510, a vinyl ester, showed good resistance to attack in the six tests. QuaCorr, a furan resin, was good in five tests and fair in one test. The condition of Atlac 711, a polyester, was good in two tests and fair in four tests. Hetron 92, a chlorinated polyester, showed poor resistance to attack in the six tests.

Effect of Magnesium Oxide on Corrosion by Slurry: A spool of specimens was installed at each of four test locations in the scrubber systems for exposure only while additional magnesium oxide was used to show its effect on corrosion by the slurry. Normally, the Mg^{++} concentration in the slurry is in the range of 500 to 900 ppm. Three of the spools were exposed in the venturi/spray tower system, one each at test locations 1004, 1005, and 1008. The fourth spool was exposed in the TCA system at test location 2005. The exposure period for the four spools varied from 220 to 2680 hours and the MgO additions were from 2000 to 14,200 ppm. Lime slurry was used during some runs and limestone slurry in others. The following tabulation lists corrosion rates for tests conducted with and without the addition of magnesium oxide.

Test location	1005		1004		1008		2005	
Test series	4th	E[a]	4th	E[a]	4th	E[a]	4th	E[a]
Exposure time, hr.	1490	-	220	-	220	-	2680	-
MgO added, ppm	3000 to 14,200	-	5000	-	5000	-	2000 to 13,000	-
Corrosion rate, mils/yr								
Cor-Ten A or B	170	33[b]	43	56[b]	26	7[b]	40	22[b]
Mild steel A-283 or A-285	171	37[b]	26	60[b]	35	14[b]	48	21[b]

[a] Earlier tests.
[b] Average corrosion rate of earlier tests without the addition of MgO.

Results of tests at locations 1005, 1008, and 2005 show that the addition of magnesium oxide increased the corrosion rate of Cor-Ten and mild steel from 2 to 5 times the average rate for these alloys tested earlier at the same test location without additions of magnesium oxide. The tests at location 1004 with added magnesium oxide resulted in lower rates for Cor-Ten and mild steel than were experienced without additional magnesium oxide in earlier tests. It is believed that the current use of undersprays and oversprays for cleaning the mist eliminator also kept the specimens at test locations 1004 clean and thereby lowered the corrosion rates below the average rates for the previous tests.

Exhaust System

Equipment for Reheating Scrubbed Gases: After the flue gases are scrubbed, they are reheated to between 235° and 265°F by oil-fired reheaters. The original equipment used was Hauck inline reheaters. Currently, external reheaters manufactured by Bloom Engineering Company are in use. Reheating is accomplished by direct mixing of scrubbed gas and reheater exhaust. The performance of the Bloom reheaters has been much better than that of the inline reheaters. The frequency of flameouts has been greatly reduced. In general, the condition of the Bloom reheaters is good.

Stainless Steel Duct: The 316L stainless steel duct that extends from the reheater to the I.D. fan in the TCA system contained pits 17 mils deep. The pits formed under a thick coating of hard solids. The heaviest deposits, about 2 inches thick, were on the divider for the transition sections of the duct (cylindrical to rectangular) that connects the inlet of the I.D. fan to the stack.

I.D. Fans: The third interim report described a crack that occurred in one shroud of the I.D. fan for the venturi/spray tower system and the repairs made to the unit. The unit had been operated 205 days when another crack was noted at the same location. The crack originated on the periphery of the shroud in the heat-affected zone of the weld that joins a blade to the shroud. The first crack extended 4 inches (see Fig. 9), and the second crack was about the same length. Repairs were made by grinding a "V" notch on each side of the shroud in the crack and welding from both sides. The filler metal used for the weld was Type 316L stainless steel (Type 347 filler metal was used to repair the first crack). Welds of Type 316L filler metal have better ductility than those of Type 347. An inspection of the fan was made after almost 7 months of additional service, and no cracks were noted in the repaired area. No other changes of importance were observed on the I.D. fan for either scrubber system since the third series of corrosion tests was completed.

Expansion Joints: Repairs have been required frequently on the corroded expansion joints above the I.D. fan in both the venturi and TCA scrubber systems. Cold-working of the Type 316L stainless steel during fabrication and fatigue caused by vibration from operating equipment increased the susceptibility of the metal to attack. Measures that would improve corrosion resistance of the expansion joints are as follows: solution anneal the unit after fabrication, change from rectangular to cylindrical design with a longer bellows section of thicker gage, and use Inconel 625 instead of Type 316L stainless steel for this service.

Specimens Tested in Exhaust Stacks: Exposure of test specimens at test locations 1007 and 2007 at the vacuum breakers in the stacks was discontinued when the third series of tests was completed. New test locations 1014 and 2014 were established below the I.D. fans and test locations 1015 and 2015 were established above the fans in the venturi and the TCA scrubber systems, respectively. Probe-type assemblies were used to install disk-type specimens at these test locations (see Fig. 3). The temperatures of gases at these test points are usually in the range of 235° to 265°F.

Tables I and III give pertinent information on exposure conditions and results of the tests. All the specimens were heavily coated with solids.

Corrosion rates for specimens in the stack for the venturi/spray tower system were 1 to 3 mils per year above the I.D. fan (at location 1015) and 3 to 4 mils below the fan (at location 1014) without evidence of localized attack at either test location. For similar tests in the TCA stack, the rates for all alloys,on the basis of weight loss, were negligible to 1 mil per year except for Cor-Ten A and mild steel which had rates of 4 and 19 mils per year. The greatest attack occurred below the fan (at location 2014). Pitting and/or crevice corrosion occurred on most specimens in the TCA stack. The reason for localized attack of specimens in the TCA stack and not in the spray tower stack is not evident. Perhaps the stack temperature for the TCA system was lower, allowing more condensate to be present than in the stack for the venturi/spray tower system. The highly alloyed materials, Hastelloy alloys C-276 and G, Haynes 6B, Inconel 625, and Jessop 700, were not included in these tests because of low rates experienced in earlier tests at locations 1007 and 2007.

U-shaped stress specimens (see Fig. 3) of six alloys were installed (July 1975) in the inlet gas cavity of each I.D. fan in an effort to identify the cause of cracking of the I.D. fan and expansion joints above the fans. If static stresses in the fan and expansion joints caused cracking in these units, the stressed specimens should crack also. None of the specimens had failed as of August 1976. Perhaps a longer exposure for the stressed specimens is needed because the fan had been in service approximately 2-1/2 calendar years when the first crack occurred. The tests of stressed specimens are being continued.

Tanks

Effluent Hold Tanks: An effluent hold tank (EHT) 20 feet in diameter and 21 feet tall is located directly under each scrubber: item D-101 (Fig. 1) for the venturi and item D-201 (Fig. 2) for the TCA. The shells are made of A-283 carbon steel coated inside (80 mils minimum thickness) with Flakeline 103 manufactured by the Ceilcote Company. This coating is a Bisphenol-A type polyester resin filled (25-35%) with flake glass. D-101 tank was not inspected August 26, 1976, because the venturi/spray tower system was in operation.

The D-201 tank had not been used for about 5 months because of changes in slurry-handling facilities in the TCA system. The Flakeline 103 coating on the baffles and tank walls appeared to be in good condition except in an area where the coating had been removed to accommodate installation of a slurry-level sensing element in May 1975. The bare steel in the area affected was coated with a blue epoxy-base paint. After a little over a year's service, the epoxy-base coating had failed and undercutting of the Flakeline 103 coating adjacent to the bare steel had occurred. In order to obtain a reasonable service life from a protective coating, such as this one of epoxy, it is essential that the manufacturer's instructions be followed regarding cleaning of the metal and the application of coats in the order specified with proper drying time between coats and before the equipment is put in service. An application of new Flakeline 103 in damaged areas would demonstrate the repairability of the old coating, but this has not been done at Shawnee.

The bottom of the EHT was not inspected because about 6 inches of liquid and solids remained in the tank. The 8-inch-diameter pipe of Bondstrand (FRP, resin not identified) has been removed from the tank. The Type 316L stainless steel downcomer below the TCA tower was pitted under the tightly adhering scale. An unlined 4-inch carbon steel pipe inside the west wall of the tank has corroded severely after about 2-1/2 years of exposure.

The neoprene-covered agitator blades in D-201 tank are in good condition; they show moderate wear on the leading edges and some damage due to impact with hard objects. During the fourth corrosion test period, the agitator blades were lowered to within 8 inches of the tank bottoms for more thorough mixing when the liquid level was lowered to shorten the slurry residence time. The hardness of the neoprene coverings on the agitator blades is given in Table VI; these values have not changed appreciably from the original hardness values.

The venturi/spray tower system was idle October 18, 1976, and the onsite inspection engineer provided a report on the conditions of much of the equipment. The flakeline coating in EHT D-101 was generally in good condition. Hairline cracks were noted on some baffles and along the junction of the baffles with the tank wall. An area of the tank bottom that had been repaired previously with Goodyear's Pliobond cement was in good condition. The edge of the Flakeline 103 coating around the entrance pipe for the Brooks level gage had lost adhesion with the carbon steel shell. The area was scraped clean and Pliobond was applied around the pipe inlet area. Undercutting of the Flakeline 103 coating will continue to progress unless a seal prevents fluids from entering between the coating and the steel shell.

The neoprene-covered agitator blades have shown little change due to abrasion. The Durometer A2 hardness of the coating was 62 to 65 at 70°F. The covering on the shaft was in good condition, and the stabilizer blades that had been repaired previously were still intact.

Specimens Tested in Effluent Hold Tanks: Specimens were not exposed in the EHT's except for a short-term test (220 hr., see Table I, location 1008) in the venturi system which was discussed previously.

Tank D-204: During the original operation of the TCA scrubber system, tank D-204 was used for a few months as a recirculation tank. It is 5 feet in diameter, 21 feet tall, and lined with neoprene. During the latter part of the current corrosion test period, the tank was used as an EHT to reduce residence time for slurry. In order to use the tank, an 18-inch mild steel crossover and a downcomer were installed in March 1976. The addition of the downcomer and the accumulation of solids on the agitator blades increased resistance to agitation. This overloaded the electric drive motor. Figure 10 shows numerous holes that corroded in the downcomer. Failure occurred in the area where magnesium oxide was fed into the tank.

Clarifier Tank D-102: The Flakeline 103 coating in the clarifier tank D-102 for the venturi/spray tower system was in good condition. Rust was showing at a small spot on the cone-shaped bottom; this minor damage to the coating was not repaired. The mechanical equipment of Type 316L stainless steel appeared to be in good condition.

Specimens Tested in Clarifier Tanks: A spool of corrosion test specimens was suspended in the slurry 5 feet below the launder in each clarifier tank, D-102 for the venturi system and D-202 for the TCA system. These tanks are not shown in Figures 1 and 2. Tables I and III (test locations 1013 and 2013) give the results of the tests. Corrosion rates were negligible for all alloys tested in the clarifier tanks except for Cor-Ten A and mild steel A-285 which had maximum rates of 2 and 3 mils per year, respectively. Pitting and/or crevice corrosion occurred on specimens of seven alloys in the TCA clarifier tank. Only mild steel showed localized attack in the venturi system clarifier tank.

Clarified Process Water Storage Tanks: The storage tanks for clarified process water are lined with neoprene. Tank D-103 is for the venturi/spray tower system. Its lining was in good condition. The neoprene-covered agitator showed only slight wear on the edge of the blades. Some of the carbon steel nuts on the structural support for the mixers were corroded severely.

Tank D-203 is used to store clarified process water for the TCA system. This tank was practically filled with water. The lining above the waterline was in good condition. Hardness values of the lining were normal and are given in Table VI.

Hold Tank D-208: Tank D-208 was put in service after the third series of corrosion tests was completed in April 1975. During the current tests, it was used as an EHT for the venturi/spray tower system. This is the first inspection made of the tank. The wall below the water level was covered with a very thin loose scale. No deterioration of the tank was apparent.

Pumps, Neoprene-Lined Centrifugal

Liners and Covered Impellers: Neoprene-lined Centriseal pumps with neoprene-covered impellers were used in both scrubber systems for pumping slurry during the current test period. Four of these pumps (G-201, G-202, G-203, and G-205) were inspected in

August 1976. The hardness of the neoprene had not changed appreciably from the original hardness values (see Table VI). The condition of the liners and impeller covers ranged from good in pump G-203 to severely grooved and/or gouged areas in pump G-205. Most of the damage was caused by hard objects in the slurry. The greatest penetration noted was of gouges approximately 190 mils deep. Some pumps have been moved from one location to another, and in some cases, pumps have been used in both scrubber systems. Therefore, a comparative service life of the liners cannot be made based on their condition on August 26, 1976. The installation of strainers (to be discussed later) in the slurry pipelines has helped to reduce damage to pump liners.

Packing, Sleeves, and Shafts: The most frequent maintenance required for the Centriseal pumps is repacking the seal. G-205 was repacked seven times in July and eight times in August 1976. Wear of shaft sleeves has decreased since hardened sleeves have been installed, but new sleeves are required occasionally. The life of packing and sleeves depends greatly on the condition of the shaft. Worn shafts are replaced with new ones when the service life of sleeves and packing are extremely short.

Piping

When the scrubber systems were put in operation in 1972, most of the piping was either neoprene-lined carbon steel or stainless steel. Since that time, many modifications have been made to the systems in order to evaluate suggested procedures for improving the processes. On occasions when neither neoprene-lined pipe nor stainless steel pipe was immediately available, unlined carbon steel pipe was used.

Neoprene-Lined Pipe: Information was given in the third interim report (March 1976) concerning blisters that formed in a neoprene-lined, 4-inch pipe that had been in service for about 14,000 hours. One blister was dissected, and it was obvious that it had formed by collection of fluid between the carbon steel shell and the lining. This blister was located in an ell upstream from control valve 1047 in the slurry line to the tangential nozzles. Blisters in this area of the pipe lining have not changed in number or size; however, several smaller blisters have been noted in the 4-inch pipe to the bull nozzle. These have not changed in size since they were first noted by the onsite inspection engineer several months ago. The venturi/spray tower system had been operated 845 days as of June 14, 1976.

Blistering of neoprene lining in a tower was discussed in the section "Scrubber Towers." In that case, the lining consists of several layers, and the blister that was dissected had formed by collection of fluid between the first and second layers.

Stainless Steel, Types 304 and 316L: Type 316L stainless steel piping was installed at several locations in the scrubber systems. However, when Type 316L pipe was not available, a few sections of Type 304 stainless steel pipe were installed. For pipe carrying lime/limestone slurry, with its external surfaces exposed to atmospheric conditions only, attack would be due mainly to erosion inside the pipe, and pitting inside would not be a problem while the slurry was moving. The erosion rate would be about equal for Types 304 and 316L stainless steel. However, during idle periods if slurry were left in the lines, Type 304 stainless steel pipe would pit more inside than would Type 316L pipe.

Inside the afterscrubber tower where Types 304 and 316L stainless steel pipes are used for spray headers, external surfaces of the pipe are exposed to the corrosive environment; the surface of Type 304 stainless steel pipe pitted much more than that of Type 316L pipe.

Carbon Steel, Unlined: The life of unlined carbon steel pipe used to transfer lime/limestone slurry is short compared with that of 300 series stainless steel pipe. The limited corrosion resistance of carbon steel and the abrasiveness of flowing slurry result in severe erosion-corrosion, especially where the flow changes direction and turbulence is encountered. Also, localized corrosion progresses rapidly under deposits of solids if conditions are such that abrasion is not a factor. Figure 10 shows an example of this type of failure in a TCA downcomer. Test specimens of carbon steel (mild steel) have been exposed in all test locations of each scrubber system. Corrosion rates have ranged from 1 to 250 mils per year. Magnesium oxide was added to the slurry during part of the fourth series of tests. Specimens of mild steel A-283, which were exposed only while magnesium oxide was being used, were corroded at rates 2 to 5 times greater than specimens tested before the additions were made.

Strainers

Two single-element Hayward strainers used in parallel were installed in the discharge lines from pumps G-201 and G-204 in May 1975. These are vertical-type basket strainers. Six-inch units were installed near pump G-204 in the venturi spray tower system and 8-inch units near pump G-201 in the TCA system. The materials of construction of the Hayward strainers were as follows: body, cast steel; trim, malleable iron; basket, Type 316 stainless steel plate 20 mils thick and perforated with 3/8-inch-diameter holes; and cover gasket, neoprene. After approximately 15 months of operation, the general condition of the strainers is about the same for both scrubber systems. The 6-inch strainer units had erosion of the basket support ledge, minor erosion of the lower half of the inlet flange face in the south unit, and a 1/4-inch-deep eroded area in the discharge throat. The north strainer had grooves 1/2 inch deep in the outlet throat, two eroded areas on the basket support flange, and erosion of the lower half of the inlet flange. The Type 316 stainless steel baskets in both units of the two scrubber systems were in good condition except for mechanical damage, which could have been done during cleaning. Deterioration of the basket support ledge could be due, in part, to galvanic action from contact of dissimilar metals. The use of a thick (1/8-1/4 inch) neoprene gasket designed to prevent contact at both the flange and side walls of the Type 316 strainer with the cast steel body could be beneficial.

Valves

Fabri knife-gate valves were installed in May 1975 in the slurry line upstream and downstream from each Hayward strainer. Each of the two strainers requires two valves in order to isolate it for cleaning. The valves perform better if installed so that the pressure is against the inlet side of the knife gate when the valves are closed. The wetted part of the valves is Type 316 stainless steel; all other parts are cast or fabricated carbon steel. Two problems have been encountered with the Fabri knife-gate valves. Solids collect in the seat and prevent complete closing of the gate. Also, the O ring that makes a seal with the gate gets torn or cut frequently when the gate is being opened or closed. The damage is done by hard scale that builds on the gate. The valves can be operated without the O rings, so the rings have been removed from the units. However, slight leakage may occur when a basket is being emptied, but this is not a serious problem.

Effect of Molybdenum Content in Alloys

Previous corrosion tests conducted in the lime/limestone test facilities for removing sulfur dioxide from stack gases showed severe pitting and crevice corrosion of ordinary stainless steels. For many years molybdenum has been considered a valuable alloying element to inhibit pitting attack of stainless steels. The American Iron and Steel Institute (AISI) appointed a committee of stainless steel producers to investigate further the role of molybdenum in providing resistance of stainless steel to pitting. In May 1975 the committee invited us to participate in the study. Alloying elements other than molybdenum also affect greatly the resistance of metals to pitting and crevice corrosion.

Efforts were made to obtain sheet stock containing the minimum and maximum molybdenum contents specified for each of several alloys. Stock containing near the specified minimum content of molybdenum was available, but stock with maximum molybdenum content was not. The only AISI alloy obtained with as much as 0.5% difference in molybdenum content was Type 316L stainless steel (2.3 and 2.8% Mo). Stock was preferred that contained 2 and 3% Mo. In general, the molybdenum-containing AISI alloys are produced with molybdenum content near the minimum specified quantities.

The curve in Figure 11 shows the results of exposure of molybdenum-containing alloys in the current series of tests. The abscissa gives the molybdenum content of the alloy, and the ordinate shows the percentage of the specimens tested that were not affected by localized corrosion. The number of specimens tested ranged from seven of Type 216 stainless steel to eighteen of Type 316L (2.3% Mo content). The following stainless steels showed low resistance to pitting and crevice corrosion: Climax 18-2 and AISI Types 216, 316L, and 317L. Only 28 to 43% of the specimens tested of these alloys were without localized attack. The molybdenum content of these alloys ranged from 2 to 3.2%. The alloy Type 316L containing 2.8% Mo showed some improvement over that of Type 316L containing 2.3% Mo, but Type 317L stainless steel containing 3.2% Mo was less resistant in these tests than the Type 316L containing 2.8% Mo. Climax 18-2 (18% Cr, 2% Mo) appeared to be as resistant as Type 317L stainless steel. The reason for these inconsistencies is not evident. However, it is evident that 3.2% Mo is not enough to prevent localized attack of the low alloy stainless steel in the lime/limestone scrubber systems for cleaning stack gases.

The effect of other alloying elements, such as chromium, nickel, and manganese, is also shown in Figure 11. Type 216 stainless steel was developed as a substitute for Type 316 by replacing part of the nickel in Type 316 with manganese. The stock of Type 216 stainless steel used in these tests contained 19.5% Cr, 6.8% Ni, 8.2% Mn, and 2.3% Mo. This alloy showed some improvement (43% of specimens without pitting or crevices) over the other alloys discussed thus far.

Nitronic 50, AL 6X, and AL 29-4 showed 67, 77, and 79% resistance to localized attack, respectively. Their molybdenum contents ranged from 2.25 to 6.4%. The AL 29-4 (29% Cr, 4% Mo) was the most resistant of the three alloys. The cost of materials above alloy AL 29-4 on the curve increases rapidly; these are highly alloyed materials. See Table IV for analyses of all alloys tested.

The alloy Hastelloy G contained 6.7% Mo and 92% of the specimens showed good resistance. Inconel 625 and Hastelloy C-276 contained 9 and 16.3% Mo, respectively; these alloys showed 100% resistance to pitting and crevice corrosion. Hastelloy G, Inconel 625, and Hastelloy C-276 are nickel-base alloys. Their resistance to chemical attack is due to nickel, chromium, and molybdenum content.

Compilation of Corrosion Data

Table VIII is a compilation of data for alloys and plastics tested in the two scrubber systems without identifying test conditions. This table summarizes information on general corrosion (based on weight loss), pitting, and crevice corrosion for the alloys and it gives a comparative evaluation for the plastics tested. The alloys are listed in the approximate order of decreasing corrosion resistance.

The five alloys that showed the greatest resistance to corrosion were Hastelloy C-276, Inconel 625, Hastelloy G, Haynes 6B, and Multimet (alloys Hastelloy G and Multimet were not included in previous corrosion tests conducted at the Shawnee Test Facility). On the basis of weight loss, the corrosion rates ranged from negligible to 1 mil per year. Localized attack did not occur on Hastelloy C-276 and Incoloy 625, but it did occur on one or more specimens of the three other alloys.

Ten other alloys form another group with maximum corrosion rates of 3 and 4 mils per year. Pitting and/or crevice corrosion was common on some specimens of all the alloys except Zirconium 702, which showed no evidence of localized attack. Only a few specimens were tested of stainless steel alloys Type 216, Carpenter 7-Mo, and Type 201. More tests of these alloys are needed for a better comparison with other alloys. Cor-Ten A and mild steel A-283 had corrosion rates that ranged from 1 to 170 mils per year.

Of the five resin-type FRP's tested, all specimens of Bondstrand 4000 (epoxy) and Derakane 510 (vinyl ester) were in good condition after the test. QuaCorr (furan) had eleven good and one fair; Atlac 711 (polyester) had eight good and four fair; and Hetron (chlorinated polyester) had two fair and ten poor.

Acknowledgments

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The following firms supplied materials for preparing corrosion test specimens:

Alloys (sheet and filler metal)

Allegheny Ludlum Steel Corporation
Armco Steel Corporation
Carpenter Technology Corporation
Climax Molybdenum Company
Colt Industries
G. O. Carlson, Incorporated
Huntington Alloys
Jessop Steel Corporation
Metal Goods, Incorporated
Cabot Corporation, Stellite Division
Teledyne Wah Chang Albany
United States Steel Corporation

Plastics (fiberglass-reinforced)

Ameron, Corrosion Control Division
Dow Chemical Company
Hooker Chemical Corporation, Durez Division
ICI United States, Incorporated
Quaker Oats Company

Table I

Corrosion Tests[a] Conducted in the Venturi/Spray Tower System of the Alkaline - Wet-Scrubbing Process for Sulfur Dioxide Removal from Stack Gas at Shawnee Steam Plant

[Test period--7/23/75 to 3/24/76 (626-1A through factorial tests); operating time--4666 hours or 194.4 days; and idle time--1214 hours or 50.6 days]

Corrosion specimens Exposed in	Inlet gas	Gas and liquor	Gas and liquor	Gas and liquor	Gas and droplets	Gas and droplets	Exhaust gas (heated)	Exhaust gas (heated)	Effluent liquor	Liquor in clarifier
Locations (See Fig. 1), Ref. No.	1002	1006	1005	1005[b]	1004	1004[c]	1014	1015	1008[c]	1013
Gas										
Temperature, °F	275-330	125-130	125-130	125-130	125-130	125-130	235-265	235-265	-	-
Velocity, ft/sec	32-67	4.5-9.4	4.5-9.4	3.6-6.3	4.5-9.4	9.4	32-63	32-63	-	-
Flow rate, 1000's acfm at 330°F	17-35	15-30	15-30	20-30	15-30	30	17-35	17-35	-	-
Composition, % by volume										
SO_2	0.2-0.4	-	-	-	-	-	0.02-0.10	0.02-0.10	-	-
CO_2	10-18	-	-	-	-	-	11-19	11-19	-	-
O_2	5-15	-	-	-	-	-	6-16	6-16	-	-
H_2O	8-15	-	-	-	-	-	9-16	9-16	-	-
HCl	0.01	-	-	-	-	-	-	-	-	-
N_2	74±	-	-	-	-	-	69±	69±	-	-
Flyash, gr/std. ft³	2-7	-	-	-	-	-	0.01-0.04	0.01-0.04	-	-
Liquor										
Temperature, °F	-	-	-	-	-	-	-	-	90-130	70-100
Solids, undissolved, % by wt.	-	-	-	-	-	-	-	-	8-18	0-35
Solids, dissolved, % by wt.	-	-	-	-	-	-	-	-	0.5-3.4	0-3.4
pH	-	-	-	-	-	-	-	-	4.3-6.5	5.0-9.5
Ionic composition, ppm										
$SO_3^=$	-	-	-	-	-	-	-	-	40-3900	40-3900
$CO_3^=$	-	-	-	-	-	-	-	-	5-150	5-150
$SO_4^=$	-	-	-	-	-	-	-	-	400-1400	400-1400
Ca^{++}	-	-	-	-	-	-	-	-	540-3000	540-3000
Mg^{++}	-	-	-	-	-	-	-	-	100-5500	100-5500
Na^+	-	-	-	-	-	-	-	-	60-110	60-110
K^+	-	-	-	-	-	-	-	-	90-150	90-150
Cl^-	-	-	-	-	-	-	-	-	3300-5700	3300-5700

Table I

(Continued)

Corrosion specimens										
Exposed in	Inlet gas	Gas and liquor	Gas and liquor	Gas and liquor	Gas and droplets	Gas and droplets	Exhaust gas (heated)	Exhaust gas (heated)	Effluent liquor	Liquor in clarifier
Locations (See Fig. 1), Ref. No. . .	1002	1006	1005	1005[b]	1004	1004[c]	1014	1015	1008[c]	1013
Corrosion rate of metals, mils/yr[d]										
AL 6X, weld AL 6X	-	< 1	Neg.	-[e]	-[e], P17	-	4	1	Neg.	-
AL 29-4, weld AL 29-4	< 1, Pm	-	< 1	< 1	< 1, Pm	-	3	2	Neg.	-
Carpenter 7-Mo, weld 316L	-	-	< 1, P5	-	< 1[e], P5	-	-	-	-	-
Climax 18-2, weld Climax 18-2	-	-	< 1, P10	-[e], P6	-[e], P6	-	3	2	Neg.	-
Cor-Ten A, weld E8018-C3	42	> 108	21	170	9, P11	43	4	3	26, P5	2
Hastelloy C-276, weld Hastelloy C-276	< 1	< 1	< 1	< 1	Neg.	Neg.	-	-	-	Neg.
Hastelloy G, weld Hastelloy G	< 1	< 1	Neg.	< 1	Neg.	< 1	-	-	Neg.	-
Haynes 6B, weld Haynes No. 25	1	< 1	Neg.	P9	Neg.	Neg.	-	-	Neg.	Neg.
Inconel 625, weld Inconel 625	< 1	< 1	Neg.	< 1	Neg.	Neg.	-	-	-	Neg.
Jessop 700, weld Comete S2	-	< 1, -[e]	< 1	P7	Neg.	-	3	-	-	-
Mild steel A-285, weld E6012	28	-	-	171	-	26	4	2	35, P10	3[e]
Multimet, weld Multimet	-	-	Neg.	Neg.	Neg.	-	-	-	Neg.	-
Nitronic 50, weld Nitronic 50	-	-[e], Pm	-	-	-	< 1	3	2	Neg.	Neg.
Nitronic 50M, weld Nitronic 50	1, Pm	-[e], P2	< 1, P4	-[e]	Neg.	1[e]	3	2	Neg.	Neg.
Type 201, weld Type 316	5, P7	-	-	-	-	-	3	2	-	-
Type 216, weld Type 216	-	-	-	-	-	-	3	2	Neg.	-
Type 316L[f], weld Type 316L	1, Pm	1[e], Pm	-[e], Pm	-[e]	-[e], P2	1[e], P1	3	2	Neg.	Neg.
Type 316L[g], weld Type 316L	-	1[e], Pm	< 1	-	-[e]	< 1[e]	4	2	Neg.	Neg.
Type 317L[h], weld Type 309Cb	-	-	-	-	-	-	3	2	Neg.	-
Zirconium 702, weld Ziconium 702 . . .	-	-	Neg.	Neg.	Neg.	Neg.	4	2	Neg.	Neg.
Evaluation of plastics[i]										
Atlac 711, polyester	-	Fair	Fair	Good	Good	Good	-	-	Good	Good
Bondstrand 4000, epoxy	-	Good	Good	Good	Good	Good	-	-	Good	Good
Derakane 510, vinyl ester	-	Good	Good	Good	Good	Good	-	-	Good	Good
Hetron 92, chlorinated polyester . . .	-	Poor	Poor	Poor	Poor	Fair	-	-	Fair	Poor
QuaCorr, furan resin	-	Good	Good	Good	Fair	Good	-	-	Good	Good

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[a] The tests conducted at location 1011 were affected greatly by erosion in addition to corrosion. Results of these tests are given in Table II.

[b] Specimens exposed 1490 hours (3/24-6/14/76) with magnesium oxide added to the slurry.

[c] Specimens exposed 220 hours (1/26-2/5/76) with a nominal 5000 ppm magnesium oxide added to limestone slurry.

[d] Negligible (Neg.) indicates corrosion rates of less than 0.05 mil per year, and < 1 indicates corrosion rates from 0.05 to 0.49 mil per year; "P" preceding a number indicates pitting during the exposure period to the depth in mils shown by the number; and "Pm" indicates minute pits. Where localized attack is more severe than the rate determined by weight loss, no rate is given for general corrosion.

[e] Crevice corrosion at Teflon insulator.

[f] Contains 2.3% by weight molybdenum.

[g] Contains 2.8% by weight molybdenum.

[h] Contains 3.2% by weight molybdenum.

[i] Evaluation: Good, little or no change in condition of specimen; fair, definite change, probably could be used; poor, failed or severely damaged.

Table II

Erosion-Corrosion[a] of Specimens Tested Below the Venturi

Test specimens		
Exposed in	Gas and spray	
Location (See Fig. 1), Ref. No.	1011	1011
Exposure period	7/23 to 11/17/75	12/24/75 to 3/24/76
Operating time, hr	2370	1580
Idle time, hr	440	600
Gas and spray		
Temperature, °F	80–170	80–170
Velocity, ft/sec	40–100	40–100
Flow rate, 1000 acfm at 330°F	15–30	15–30
Corrosion rate[b], mils/yr		
AL 6X, weld AL 6X	20	5
AL 29–4, weld AL 29–4	14	4
Climax 18–2, weld Climax 18–2	32	7[c], P6
Cor–Ten A, weld E8018–C3	> 2120	> 2060
Hastelloy C–276, weld Hastelloy C–276	44	10
Haynes 6B, weld Haynes No. 25	9	3
Inconel 625, weld Inconel 625	29	12
Jessop 700, weld Comete S2	31	17
Mild steel A–285, weld E6012	> 1855	> 2780
Multimet, weld Multimet	26	19
Nitronic 50M, weld Nitronic 50	16[c]	21
Type 216, weld Type 216	12	19, P2
Type 316L[d], weld Type 316L	12[c]	25[c], P7
Type 316L[e], weld Type 316L	10[c]	18[c], P23
Type 317L[f], weld Type 317L	9[c]	9[c], Pm
Zirconium 702, weld Zirconium 702	6	20

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[a] The results of tests conducted at other locations in the venturi/spray tower system at which the attack of alloys was mainly corrosion (negligible erosion) are given in Table I .

[b] "P" preceeding a number indicates pitting during the exposure period to the depth in mils shown by the number; "Pm" indicates minute pits. The sign ">" indicates that the specimen failed and the penetration rate in mils per year was greater than the number given.

[c] Crevice corrosion at Teflon insulator.

[d] Contains 2.3% by weight molybdenum.

[e] Contains 2.8% by weight molybdenum.

[f] Contains 3.2% by weight molybdenum.

Table III

Corrosion Tests Conducted in the TCA System of the Alkaline - Wet-Scrubbing Process for Sulfur Dioxide Removal from Stack Gas at Shawnee Steam Plant

[Test period--7/19/75 to 3/17/76 (553-2A through factorial tests); operating time--4990 hours or 207.9 days; and idle time--821 hours or 34.2 days]

Corrosion specimens								
Exposed in	Inlet gas	Gas and liquor	Gas and droplets	Gas and droplets	Gas and mist	Exhaust gas (heated)	Exhaust gas (heated)	Liquor in clarifier
Locations (See Fig. 2), Ref. No.	2002	2006	2005	2005[a]	2004	2014	2015	2013
Gas								
Temperature, °F	260-310	70-130	70-125	70-125	70-125	235-265	235-265	-
Velocity, ft/sec	30-45	8.4-12.5	8.4-12.5	8.4-12.5	8.4-12.5	30-45	30-45	-
Flow rate, 1000's acfm at 300°F	20-30	15-20	15-20	15-20	15-20	20-30	20-30	-
Composition, % by volume								
SO_2	0.2-0.4	-	-	-	-	0.02-0.10	0.02-0.10	-
CO_2	10-18	-	-	-	-	11-19	11-19	-
O_2	5-15	-	-	-	-	6-16	6-16	-
H_2O	8-15	-	-	-	-	9-16	9-16	-
HCl	0.01	-	-	-	-	-	-	-
N_2	74±	-	-	-	-	69±	69±	-
Flyash, gr/std. ft^3	2-7	-	-	-	-	0.01-0.04	0.01-0.04	-
Liquor								
Temperature, °F	-	-	-	-	-	-	-	85-100
Solids, undissolved, % by wt	-	-	-	-	-	-	-	0-40
Solids, dissolved, % by wt	-	-	-	-	-	-	-	0.3-2.0
pH	-	-	-	-	-	-	-	4.3-6.3
Ionic composition, ppm								
$SO_3^{=}$	-	-	-	-	-	-	-	50-600
$CO_3^{=}$	-	-	-	-	-	-	-	20-170
$SO_4^{=}$	-	-	-	-	-	-	-	600-2300
Ca^{++}	-	-	-	-	-	-	-	800-2000
Mg^{++}	-	-	-	-	-	-	-	280-600
Na^{+}	-	-	-	-	-	-	-	35-70
K^{+}	-	-	-	-	-	-	-	55-85
Cl^{-}	-	-	-	-	-	-	-	1700-3900

Table III

(Continued)

Corrosion specimens								
Exposed in	Inlet gas	Gas and liquor	Gas and droplets	Gas and droplets	Gas and mist	Exhaust gas (heated)	Exhaust gas (heated)	Liquor in clarifier
Locations (See Fig. 2), Ref. No. . .	2002	2006	2005	2005[a]	2004	2014	2015	2013
Corrosion rate of metals, mils/yr[b]								
AL 6X, weld AL 6X	-	-	Neg.	Neg.	P2	-[c], Pm	Neg.	Neg.
AL 29-4, weld AL 29-4	< 1	-	Neg.	Neg.	Neg.	-[c], P2	Neg.	Neg.
Climax 18-2, weld Climax 18-2	-	-[c], P7	-[c], Pm	< 1, P14	-[c]	1, Pm	< 1, Pm	Neg.
Cor-Ten A, weld E8018-C3	3, Pm	42	26	40	19	4	1	2[c], P7
Hastelloy C-276, weld Hastelloy C-276	< 1	< 1	Neg.	Neg.	Neg.	-	-	-
Hastelloy G, weld Hastelloy G.	< 1	< 1	Neg.	Neg.	-[c]	-	-	-
Haynes 6B, weld Haynes No. 25	< 1	< 1	Neg.	-[c]	-[c]	-	-	Neg.
Inconel 625, weld Inconel 625	-	< 1	Neg.	Neg.	Neg.	-	-	Neg.
Jessop 700, weld Comete S2	< 1	< 1	Neg.	Neg.	-[c], Pm	1	P1	-
Mild steel A-285, weld E6012	3, Pm	-	-	48	-	4	1	2[c], P9
Multimet, weld Multimet	-	< 1	-	Neg.	Neg.	1, P4	Neg.	Neg.
Nitronic 50, weld Nitronic 50	< 1	-	-[c]	-	-	-	-	-[c]
Nitronic 50M, weld Nitronic 50	< 1	1[c]	-[c]	< 1, P2	-[c]	1, Pm	< 1, Pm	Neg.
Type 201, weld Type 316	-	-	-	-	-	1[c], Pm	< 1, -[c]	-
Type 216, weld Type 216	< 1, Pm	-	-	-	-	2, P4	-[c], Pm	Pm
Type 316L[d], weld Type 316L	< 1, Pm	-[c], P8	-[c]	< 1[c]	-[c], Pm	2, Pm	< 1	Pm
Type 316L[e], weld Type 316L	-	1[c]	-[c]	-	-[c], Pm	2, Pm	< 1, Pm	Pm
Type 317L[f], weld Type 309Cb	-	1[c]	< 1	-	-[c], Pm	1, Pm	Pm	Pm
Zirconium 702, weld Zirconium 702 . .	-	1	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Evaluation of plastics[g]								
Atlac 711, polyester	-	Good	Fair	Good	Fair	-	-	Good
Bondstrand 4000, epoxy	-	Good	Good	Good	Good	-	-	Good
Derakane 510, vinyl ester.	-	Good	Good	Good	Good	-	-	Good
Hetron 92, chlorinated polyester . . .	-	Poor	Poor	Poor	Poor	-	-	Poor
QuaCorr, furan resin	-	Good	Good	Good	Good	-	-	Good

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[a] Specimens exposed 2680 hours (4/5-8/24/76) with 2,000 to 13,000 ppm MgO added to the slurry.

[b] Negligible (Neg.) indicates corrosion rates of less than 0.05 mil per year, and < 1 indicates corrosion rates from 0.05 to 0.49 mil per year; "P" preceding a number indicates pitting during the exposure period to the depth in mils shown by the number; "Pm" indicates minute pits. Where localized attack is more severe than the rate determined by weight loss, no rate is given for general corrosion.

[c] Crevice corrosion at Teflon insulator

[d] Contains 2.3% by weight molybdenum.

[e] Contains 2.8% by weight molybdenum.

[f] Contains 3.2% by weight molybdenum.

[g] Evaluation: Good, little or no change in condition of specimen; fair, definite change, probably could be used; poor, failed or severely damaged.

Table IV

Composition of Alloys Tested in the Alkaline — Wet-Scrubbing Systems for Sulfur Dioxide Removal from Stack Gas at Shawnee Steam Plant

Alloys	Chemical analysis, %												
	C	Cr	Ni	Fe	Cu	Mo	Mn	Si	P	S	Al	Ti	Others
AL 6X^a	0.027	20.32	24.17	Bal.	-	6.42	1.46	0.56	0.023	0.004	-	-	N, 0.03
AL 29-4^a	0.004	29.3	0.12	Bal.	-	3.95	0.10	0.05	0.013	0.013	-	-	N, 0.010
Carpenter 7-Mo^a	0.05	27.07	4.25	Bal.	0.14	1.44	0.50	0.38	0.022	0.013	-	-	-
Climax 18-2^a	0.016	18.44	0.39	Bal.	0.21	2.08	0.4	0.39	-	-	-	0.33	N, 0.013
Cor-Ten A^a	0.11	0.66	0.33	Bal.	0.36	-	0.39	0.44	0.098	0.026	-	-	-
Hastelloy C-276^a	0.002	15.87	Bal.	5.96	-	16.32	0.49	< 0.01	0.012	0.010	-	-	Co, 1.84; W, 3.51; V, 0.25
Hastelloy C^a	0.02	21.72	Bal.	18.68	1.77	6.69	1.30	0.34	0.021	0.011	-	-	Co, 1.57; Cb+Ta, 2.13; W, 0.54
Haynes 6B^a	0.96	29.75	2.13	2.36	-	1.08	1.40	0.36	-	-	-	-	Co, Bal.; W, 4.30
Inconel 625	0.1^b	20-23	Bal.	5.00^b	-	8-10	0.5^b	0.5^b	0.015^b	0.015^b	0.4^b	0.4^b	Co, 1.0^b; Cb+Ta, 3.15-4.15
Jessop 700	0.03	21.00	25.00	Bal.	-	4.5	1.70	0.50	-	-	-	-	Cb, 0.30
Mild steel A-285	0.35^b	-	-	Bal.	0.35^b	-	0.80^b	-	0.05^b	0.05^b	-	-	-
Multimet	0.2^b	18-22.5	18-22	Bal.	-	2.75-3.75	-	-	-	-	-	-	Cb, 0.75-1.5; Co, 18-22; N, 0.1-0.2; W, 2-3
Nitronic 50	0.06^b	20.5-23.5	11.5-13.5	Bal.	-	1.5-3.0	4.0-6.0	1.0^b	0.04^b	0.03^b	-	-	N, 0.2-0.4; Cb, 0.1-0.3; V, 0.1-0.3
Nitronic 50M	0.06^b	21	14	Bal.	-	1.5-3.0	6	1.00^b	0.04^b	0.03^b	-	-	N, 0.2-0.4; Cb, 0.1-0.3; V, 0.1-0.3
Type 201	0.15^b	16-18	3.5-5.5	Bal.	-	-	5.5-7.5	1.00^b	0.06^b	0.03^b	-	-	N, 0.25
Type 216^a	0.069	19.54	6.77	Bal.	-	2.31	8.21	0.23	0.023	0.005	-	-	N, 0.358
Type 316L^a	0.020	17.1	13.8	Bal.	0.07	2.3	1.30	0.49	0.016	0.016	-	-	-
Type 316L^a	0.025	18.0	13.9	Bal.	0.05	2.77	1.38	0.54	0.011	0.012	-	-	-
Type 317L^a	0.022	18.61	13.62	Bal.	0.45	3.16	1.62	0.60	0.021	0.009	0.012	0.004	B, 0.0008; Cb, 0.02; Co, 0.17; N, 0.065
Zirconium 702	0.015	-^{c}	-	-^{c}	-	-	-	-	-	-	-	-	N, 0.05; Hf, < 0.10; Zr+Hf, > 99.2

[a] Analysis was supplied with the material.

[b] Maximum.

[c] Cr+Fe, 0.10% by weight.

Table V

Analyses[a] of Deposits in Lime/Limestone - Wet-Scrubbing Systems for Sulfur Dioxide Removal from Stack Gas at Shawnee Steam Plant

Identification of sample			Composition, % by weight					
Date	Number	Location[b]	SO_2 as $CaSO_3$	SO_3 as $CaSO_4$	CO_2 as $CaCO_3$	Cl as $CaCl_2$	Mg as MgO	Acid insoluble
Venturi System								
9/3/75	VD-1	Dry solids from gas duct at reheater outlet	4.08	70.36	Trace	Trace	1.42	24.15
9/3/75	VD-2	Black, hard scale from suction side of the ID fan casing	1.05	0.57	17.61	36.70	6.45	22.75
9/18/75	VD-1	Scale from wall above ME; top layers	1.52	67.44	Trace	Trace	0.03	31.00
10/7/75	VD-2	Soft outer fins on spray piping above ME	24.39	38.06	3.11	Trace	0.07	33.75
10/8/75	VD-1	Dust from back of ID fan blades	2.82	65.11	0.76	Trace	1.70	29.30
10/14/75	VD-1	Mud from outlet vanes of ME	56.72	5.94	9.85	1.79	0.23	25.47
10/17/75	VD-1	Scale from top of outlet ME vane	66.52	12.26	4.61	Trace	0.15	16.05
10/22/75	VD-1	Crystalline scale from tower outlet duct	0.40	59.60	1.19	0.92	0.14	37.76
11/13/75	VD-1	Top of middle vane of ME	48.41	12.33	5.94	0.33	0.24	32.55
12/2/75	VD-1	Dry solid from duct at reheater outlet	6.57	60.25	0.58	Trace	1.17	31.43
12/2/75	VD-2	Fins from reheater wall above Bloom; northwest quadrant	22.64	50.80	0.24	1.41	0.46	24.45
12/2/75	VD-3	Fins from reheater floor, extension of inlet duct	25.92	34.53	0.49	2.70	2.90	27.80
12/2/75	VD-4	Solids from back of ID fan blades	2.02	68.34	Trace	Trace	0.74	28.90
12/3/75	VD-1	Solids from tops of middle vanes of ME	35.75	21.06	2.28	0.50	0.20	40.20
1/9/76	VD-1	Deposit on failed duct in venturi chamber	7.38	73.89	Trace	0.85	0.38	17.50
1/26/76	VD-1	Solids from underside of ME	67.96	0.94	2.09	0.62	0.37	28.65
2/11/76	VD-1	Soft scale from 4-inch elbow upstream G-104 pump	56.74	22.24	18.89	Trace	0.32	1.75
TCA System								
9/2/75	TCAD-1	Chunk solids taken from top vanes of ME	1.40	42.97	Trace	Trace	0.41	53.55
9/3/75	TCAD-1	Dry solids from duct at reheater outlet	1.63	0.92	21.68	1.37	7.49	59.70
9/15/75	TCAD-1	Mud from tops of middle vanes of ME	45.94	17.26	3.25	Trace	0.15	33.40
9/23/75	TCAD-1	Solids, 2-inch thick from roof of Hauck reheater shell	0.48	53.36	0.65	Trace	0.06	42.45
9/29/75	TCAD-1	Solid from underside of outlet vane, southwest corner	62.60	6.54	1.11	Trace	0.10	29.45
10/14/75	TCAD-1	Composite from outlet vanes of ME	38.66	27.89	2.64	0.84	0.14	29.82
10/30/75	TCAD-1	Multilayered scale from No. 1 grid bars	96.58	0.43	2.70	Trace	0.05	0.25
11/14/75	TCAD-1	Multilayered scale from TCA scale deposit probe	81.03	0.70	0.85	0.03	0.13	17.25
11/19/75	TCAD-1	Solids from tops of ME vanes	42.90	20.30	5.11	Trace	0.20	27.45
11/19/75	TCAD-2	Chunks from reheater fallen to top of ME	2.60	58.01	1.83	Trace	1.13	34.25
1/12/76	TCAD-1	Deposit from side rail of ME, inlet side	35.67	21.01	0.35	0.20	0.17	42.60
1/22/76	TCAD-1	Solids from tops of ME vanes	57.03	8.64	0.70	0.72	0.09	33.55
1/29/76	TCAD-1	Solids from plugged channel on top of ME	57.43	0.02	6.75	0.37	0.21	35.60

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[a] Information taken from reports by J. B. Barkley to J. K. Metcalfe during the period 9/2/75 to 2/11/76. These analyses are given as examples and are expected to vary as the mode of operation is changed.

[b] ID, induced draft; ME, mist eliminator.

Table VI

Hardness of Neoprene Linings of Equipment in the TCA Alkaline – Wet–Scrubbing System for Sulfur Dioxide Removal from Stack Gas at Shawnee Steam Plant

(Exposure period—8/12/72 to 8/24/76, 23,060 accumulated operating hours)

Location of hardness test	Durometer "A" hardness Original[a]	Current[b]	At °F
Scrubber Tower			
Four inches above inlet gas duct (approx. elevation, 376 ft)	60–65	42–46	74
Six inches above bottom grid (approx. elevation, 380 ft)	60–65	45–48	90
Three feet above second grid, near test 2006 (approx. elevation, 386 ft)	60–65	45–48	90
Two feet below mist eliminator (approx. elevation, 403 ft)	60–65	42–45	84
One foot above mist eliminator (approx. elevation, 406 feet)	60–65	39–45	90
Clarified Process Water Storage Tank, D–203			
Above liquid level	55–60	63–64	95
Agitator in Effluent Hold Tank, D–201			
Impeller blade	–	53–59	88
Impeller stabilizer	–	48–60	88
Neoprene Lining in Centrifugal Pumps			
G–201			
Suction side of casing	54–56	56–60	79
Seal side of casing	54–56	64–68	79
Impeller	–	62–67	79
G–202			
Suction side of casing	54–56	62–67	79
Seal side of casing	54–56	61–62	79
Impeller	–	61–66	79
G–203			
Suction side of casing	54–56	64–69	78
Seal side of casing	54–56	66–70	78
Impeller	–	63–66	78
G–205			
Suction side of casing	54–56	61–67	90
Seal side of casing	54–56	65–66	90
Impeller	–	58–63	90

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[a] Values not determined by TVA but were taken from information supplied to contractors for bidding on construction. The ASTM standard D2240–68 specifies that tests for hardness of rubber be made at 73°F.

[b] The instrument used to determine the durometer hardness of the neoprene lining during inspection of the equipment (Aug. 25–27, 1976) was Shore "A2" D2240. Note that the measurements were made over a wide range of temperatures; therefore, an exact comparison of hardness values is not possible. Usually three or more tests were made in each area.

Table VII

Summary of Materials Tested to Date on Guide Vanes Below Adjustable Plug at Venturi

Specimens tested					
Alloys	Form	Guide[a]	Days	Penetration rate, in/yr[b]	Condition[c]
Haynes 6B	1/8– by 1/4–inch strip, sheared	North	16	0.2	Pits 27 mils deep on edge
Haynes 6B	1/4– by 1/4–inch rod, ground	East	164	0.4	No pits
Nitronic 50	1/2– by 1/4–inch strip, machined	North	112	> 1.7	Failed
Type 201	1/8– by 1/4–inch strip, sheared	East	90	∽ 5	Failed
Inconel 625	1/8– by 1/4–inch strip, sheared	North	90	∽ 1.2	Failed
Type 316	1/4– by 1/4–inch strip, sheared	East	16	3.3	Pits 30 mils deep
Type 316	1–inch pipe, Schedule 80	North	26	2.6	1– by 3–inch hole
Type 316	1–inch pipe, Schedule 80	East	26	2.6	3 small holes
Type 316	1–inch pipe, Schedule 80	South	45	1.5	2 small holes
Type 316	1–inch pipe, Schedule 80	West	39	1.7	1 small hole
Nonmetal[d]					
Neoprene	1/4–inch sheet	South	305	< 0.3	Not perforated
Neoprene	1/4–inch sheet	West	195	0.5	Perforated
Neoprene	1–inch hose, pneumatic	North	88	1.0	Perforated
Neoprene	1–inch hose, pneumatic	North	87	1.0	Perforated
Neoprene	1–inch hose, pneumatic	East	90	1.0	Perforated
Neoprene	1–inch hose, pneumatic	West	66	< 1.4	Slight wear

[a] The exposure conditions were more severe on the north and east guide vanes.

[b] ∽ indicates penetration rate is an estimate, since specimen evidently failed several hundred hours before test ended.

[c] All failures were at or near the midpoint.

[d] The 1/4–inch sheet consisted of several plies. The 1–inch hose has two plies of cord sandwitched between a red outer layer and a black inner layer of rubber.

Table VIII

Compilation of Corrosion Data for Tests Conducted in the Test Facilities for Removing Sulfur Dioxide from Stack Gases at Shawnee Steam Plant

(Test period: 7/19/75 to 8/24/76)

		Corrosion[a]					
		On basis of weight loss, mils/year	Specimens pitted[b]			No. of specimens with	
				Depth in mils			
Alloys	No. of tests		No.	Min.	Max.	Crevice corrosion	Pitting and/or crevice corrosion
Hastelloy C-276	12	Neg. to < 1	0	–	–	0	0
Inconel 625	12	Neg. to < 1	0	–	–	0	0
Hastelloy G	12	Neg. to < 1	0	–	–	1	1
Haynes 6B	14	Neg. to < 1	1	–	9	2	3
Multimet	10	Neg. to 1	1	–	4	0	1
Nitronic 50	9	Neg. to 3	1	–	M	3	4
AL 29-4	14	Neg. to 3	3	M	2	2	5
Jessop 700	12	Neg. to 3	3	M	7	2	5
Type 317L	9	Neg. to 3	4	–	M	2	6
Nitronic 50M	18	Neg. to 3	6	M	4	5	11
Climax 18-2	12	Neg. to 3	8	M	14	5	13
Type 316L (2.3% Mo)	18	Neg. to 3	10	M	8	8	18
Zirconium 702	15	Neg. to 4	0	–	–	0	0
AL 6X	13	Neg. to 4	3	M	17	3	6
Type 316L (2.8% Mo)	14	Neg. to 4	9	M	2	8	17
Cor-Ten A	18	1 to 170	4	M	11	1	5
Mild steel, A-285	12	1 to 171	3	M	10	2	5
		More tests are needed of the alloys below:					
Type 216	7	Neg. to 3	4	M	4	1	5
Carpenter 7-Mo	2	< 1	2	–	5	1	3
Type 201	5	< 1 to 5	2	M	7	2	4

	Evaluation,[c] No. of specimens		
Plastics	Good	Fair	Poor
Atlac 711, polyester	8	4	0
Bondstrand 4000, epoxy	12	0	0
Derakane 510, vinyl ester	12	0	0
Hetron 92, chlorinated polyester	0	2	10
QuaCorr, furan resin	11	1	0

---

[a] Data compiled from Tables I and III but does not include erosion-corrosion data in Table II.

[b] M, minute pit; the numerical values show the actual depth of penetration in mils during the test period.

[c] Evaluation: good, little or no change in condition of specimen; fair, definite change—probably could be used; poor, failed or severely damaged.

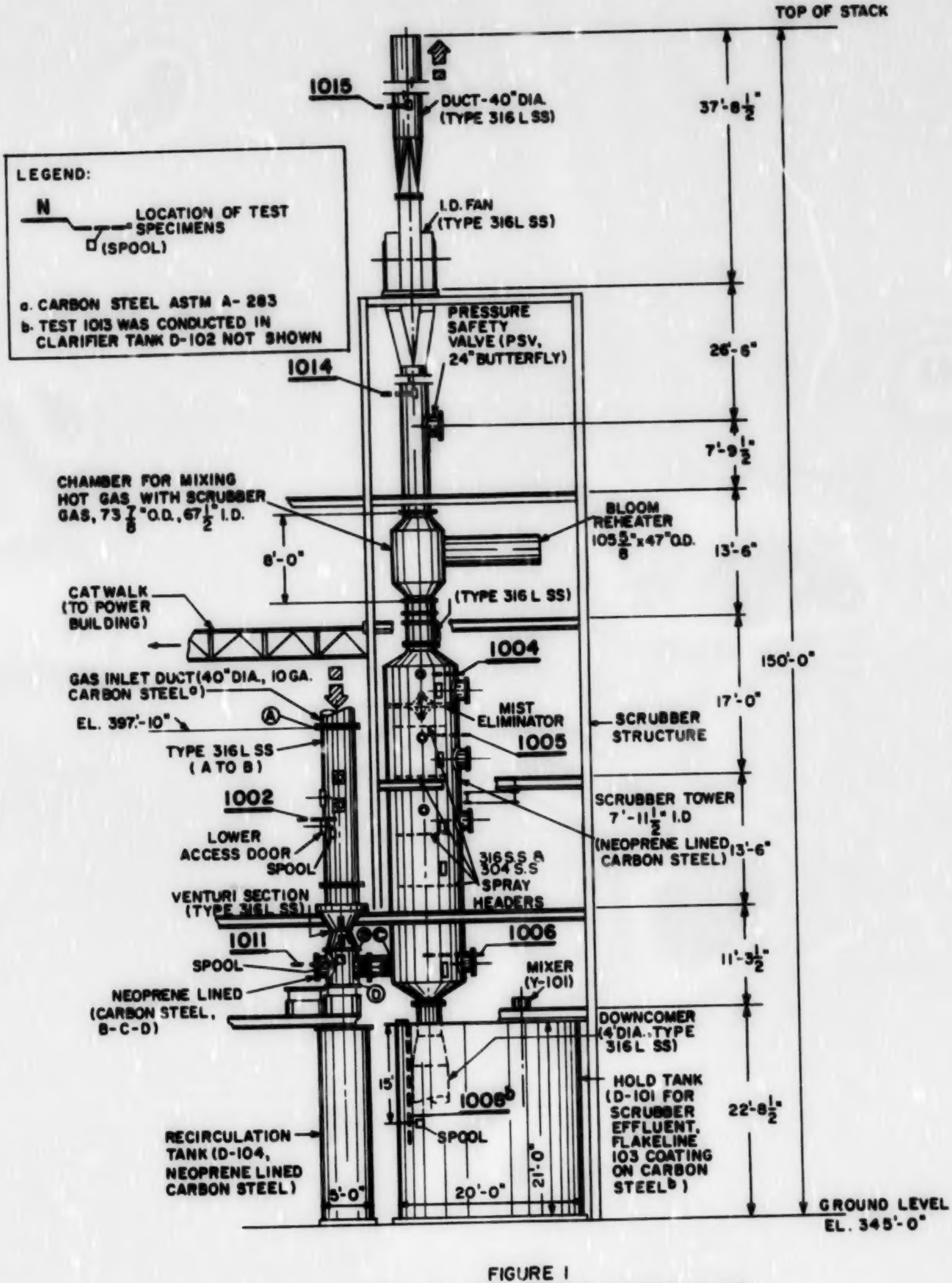

TOP OF STACK
1015
DUCT-40" DIA.
(TYPE 316 L SS)
37'-8 1/2"
LEGEND:
N
LOCATION OF TEST SPECIMENS
(SPOOL)
a. CARBON STEEL ASTM A-283
b. TEST 1013 WAS CONDUCTED IN CLARIFIER TANK D-102 NOT SHOWN
I.D. FAN
(TYPE 316L SS)
PRESSURE SAFETY VALVE (PSV, 24" BUTTERFLY)
26'-6"
1014
7'-9 1/2"
CHAMBER FOR MIXING HOT GAS WITH SCRUBBER GAS, 73 7/8" O.D., 67 1/2" I.D.
BLOOM REHEATER 105 5/8" x 47" O.D.
8'-0"
13'-6"
(TYPE 316 L SS)
CATWALK (TO POWER BUILDING)
1004
150'-0"
GAS INLET DUCT (40" DIA., 10 GA. CARBON STEEL a)
A
MIST ELIMINATOR
17'-0"
EL. 397'-10"
SCRUBBER STRUCTURE
1005
TYPE 316L SS (A TO B)
1002
SCRUBBER TOWER 7'-11 1/2" I.D
LOWER ACCESS DOOR
SPOOL
316 S.S. & 304 S.S SPRAY HEADERS
(NEOPRENE LINED CARBON STEEL)
13'-6"
VENTURI SECTION (TYPE 316L SS)
1011
1006
SPOOL
B
C
11'-3 1/2"
MIXER (Y-101)
NEOPRENE LINED (CARBON STEEL, B-C-D)
D
DOWNCOMER (4' DIA., TYPE 316L SS)
15'
1008 b
HOLD TANK (D-101 FOR SCRUBBER EFFLUENT, FLAKELINE 103 COATING ON CARBON STEEL b)
22'-8 1/2"
SPOOL
RECIRCULATION TANK (D-104, NEOPRENE LINED CARBON STEEL)
21'-0"
5'-0"
20'-0"
GROUND LEVEL EL. 345'-0"

FIGURE I
VENTURI / SPRAY TOWER SYSTEM (C-101)

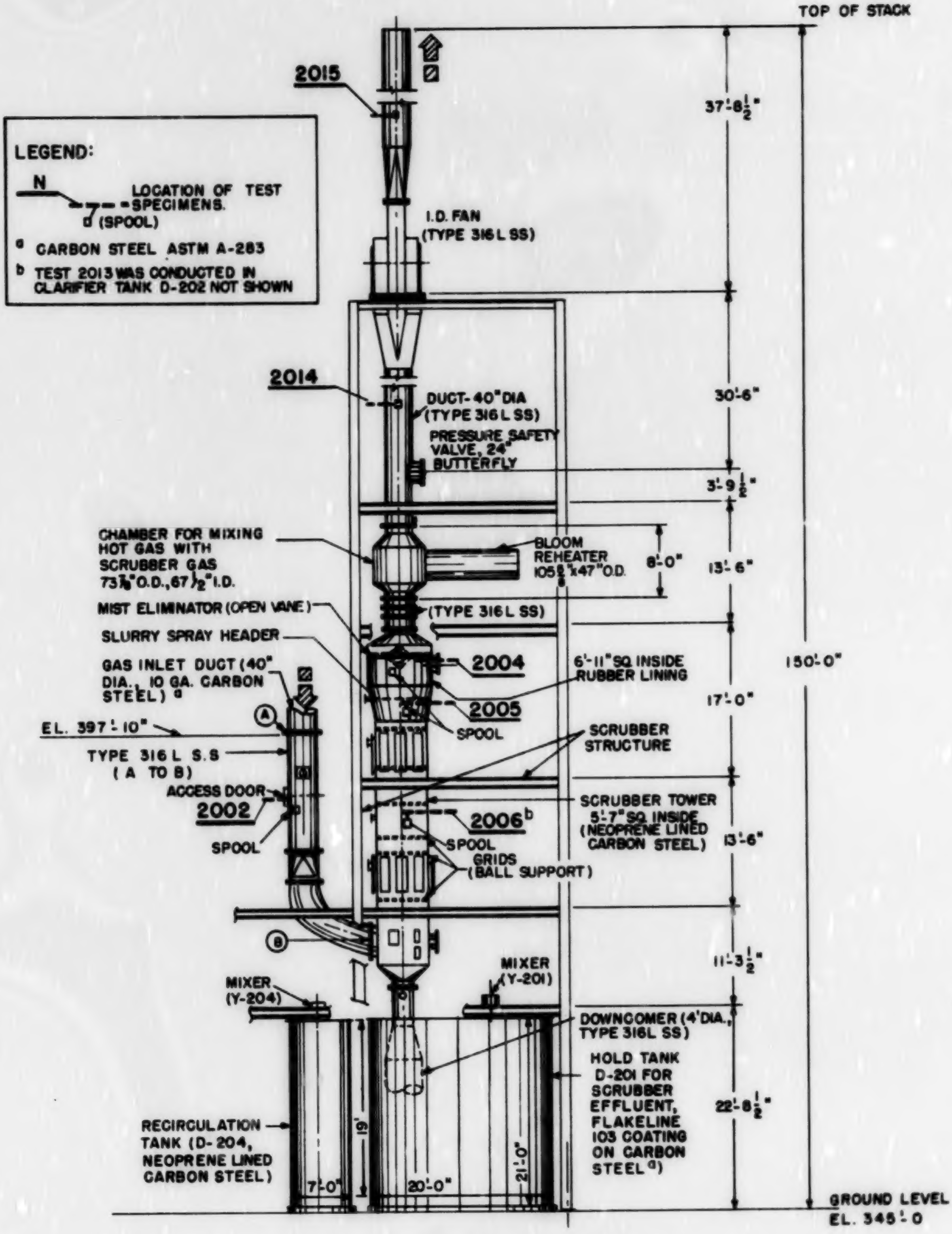
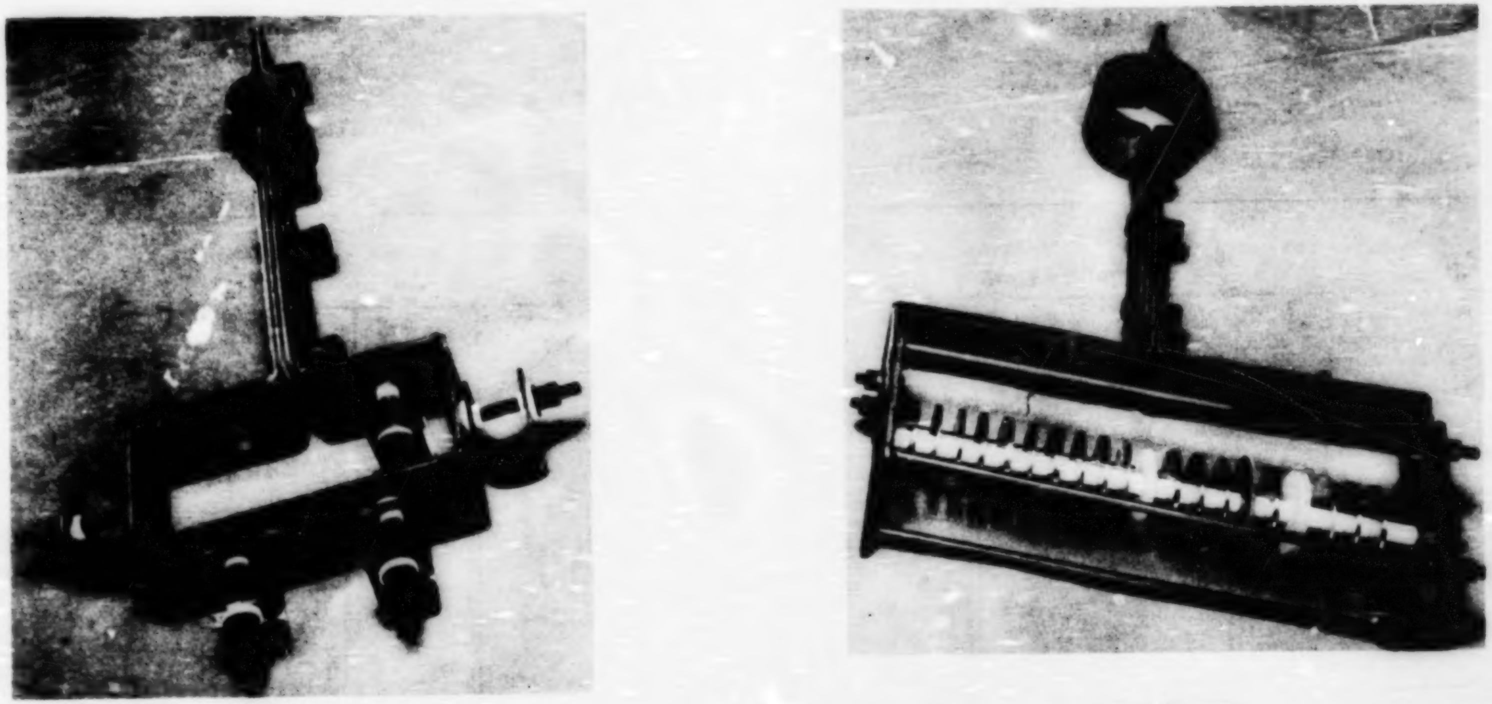
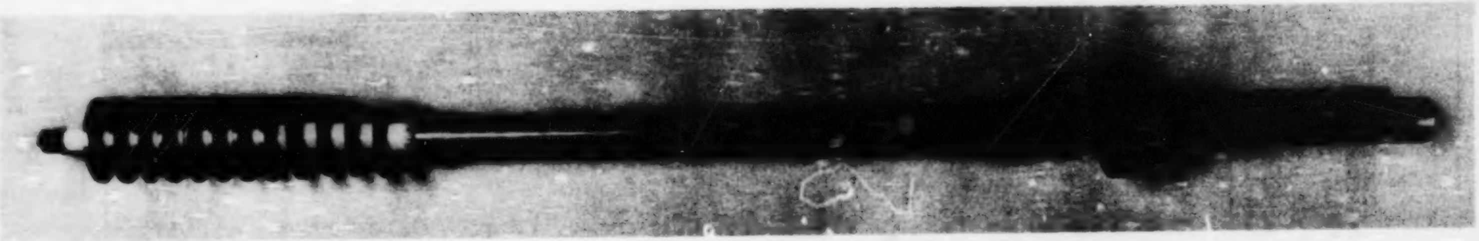

TOP OF STACK
2015
LEGEND:
N
LOCATION OF TEST SPECIMENS.
d (SPOOL)
a CARBON STEEL ASTM A-283
b TEST 2013 WAS CONDUCTED IN CLARIFIER TANK D-202 NOT SHOWN
I.D. FAN
(TYPE 316L SS)
37'-8½"
2014
DUCT-40" DIA
(TYPE 316L SS)
PRESSURE SAFETY VALVE, 24" BUTTERFLY
30'-6"
3'-9½"
CHAMBER FOR MIXING HOT GAS WITH SCRUBBER GAS 73⅞" O.D., 67½" I.D.
BLOOM REHEATER 105⅝" x 47" O.D.
6'-0"
13'-6"
MIST ELIMINATOR (OPEN VANE)
(TYPE 316L SS)
SLURRY SPRAY HEADER
2004
6'-11" SQ. INSIDE RUBBER LINING
GAS INLET DUCT (40" DIA., 10 GA. CARBON STEEL) a
2005
150'-0"
A
EL. 397'-10"
17'-0"
SPOOL
TYPE 316L S.S (A TO B)
SCRUBBER STRUCTURE
ACCESS DOOR
2002
SPOOL
2006b
SCRUBBER TOWER 5'-7" SQ. INSIDE (NEOPRENE LINED CARBON STEEL)
13'-6"
SPOOL
GRIDS (BALL SUPPORT)
B
11'-3½"
MIXER (Y-204)
MIXER (Y-201)
DOWNCOMER (4' DIA., TYPE 316L SS)
HOLD TANK D-201 FOR SCRUBBER EFFLUENT, FLAKELINE 103 COATING ON CARBON STEEL a)
22'-8½"
RECIRCULATION TANK (D-204, NEOPRENE LINED CARBON STEEL)
19'
21'-0"
7'-0"
20'-0"
GROUND LEVEL EL. 345'-0

FIGURE 2
TURBULENT CONTACT ABSORBER SYSTEM, TCA-(C-201)
(MOBILE BED)



Stressed (U-Bend)

Spool (Disk)



Probe (Disk)

FIGURE 3

Typical Assemblies of Corrosion Test Specimens

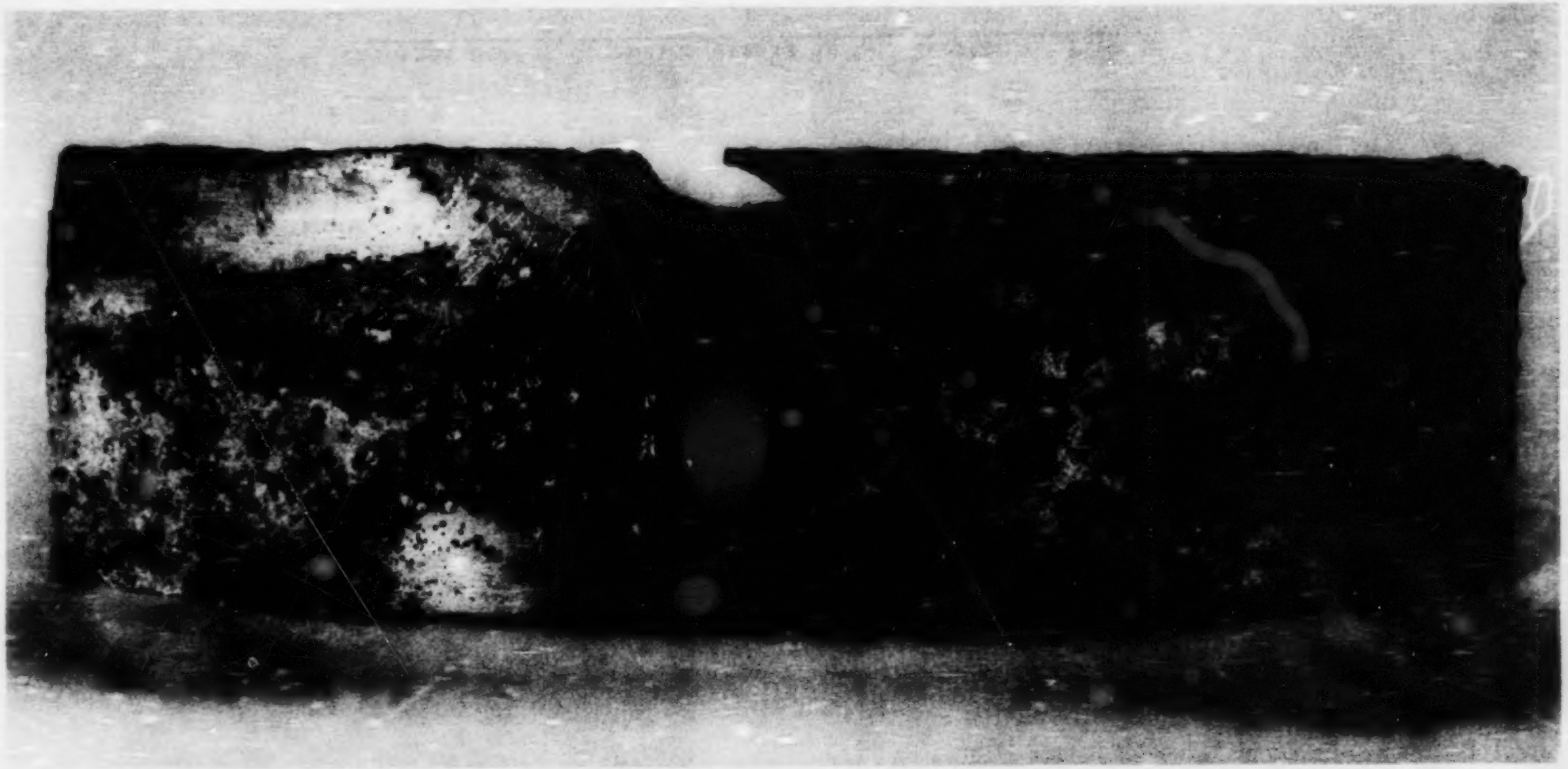


FIGURE 4

Type 316L Inlet Gas Duct That Failed Inside the Chamber

Above the Venturi After 678 Days of Operation

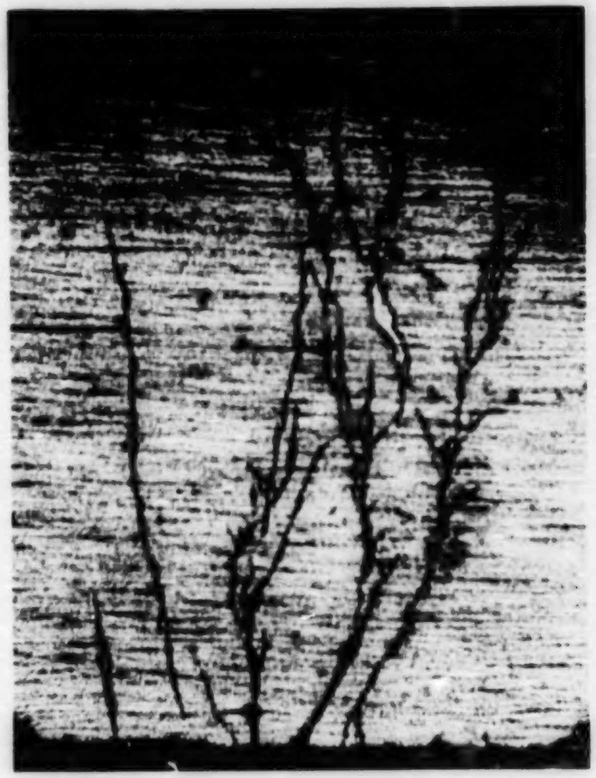


FIGURE 5 50X

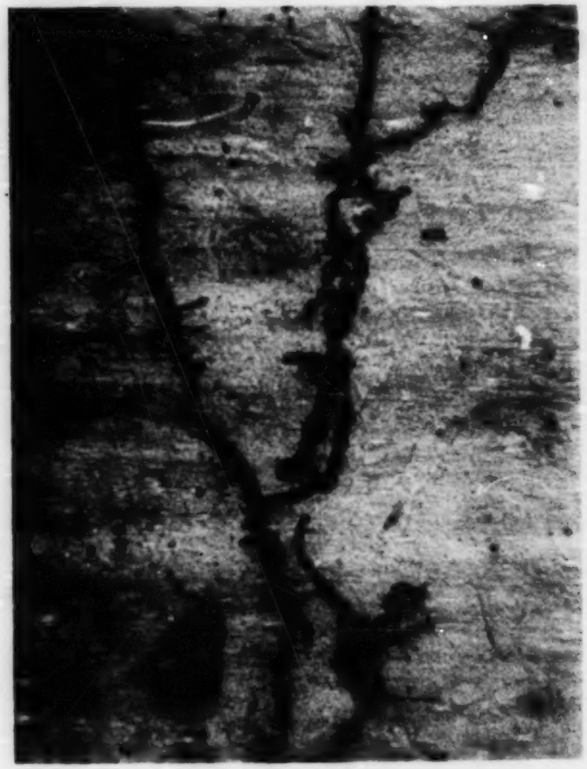


FIGURE 6 500X

Chloride Stress Corrosion Cracks in the Section of Type 316L

Stainless Steel Duct Identified in Figure 4

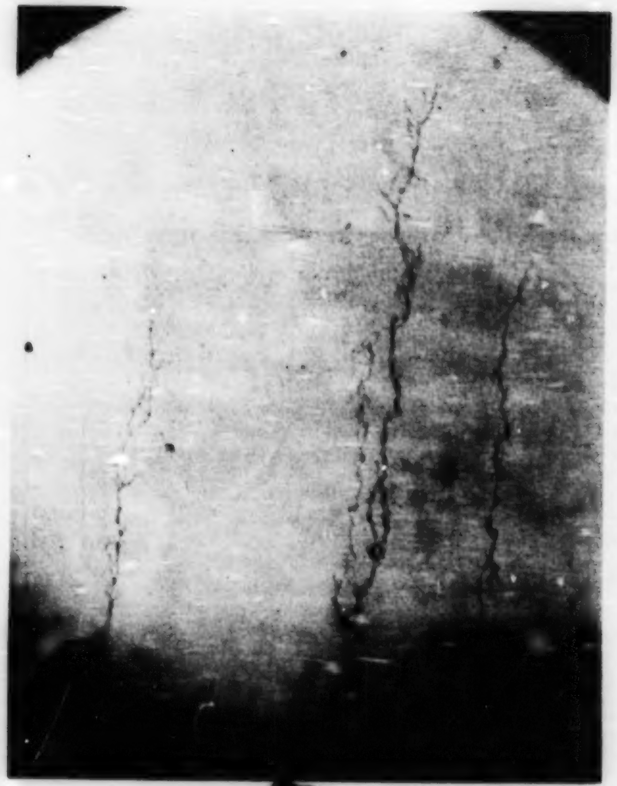


FIGURE 7 50X

Type 316L U-Stressed Specimen Cracked

in Boiling Magnesium Chloride

Solution in 34 Hours

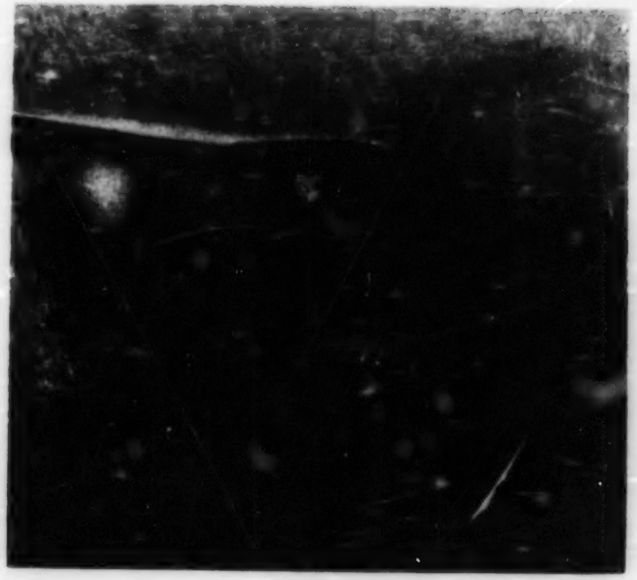


FIGURE 3

Blisters in the Neoprene Lining Above Mist

Eliminator in Venturi Spray Tower

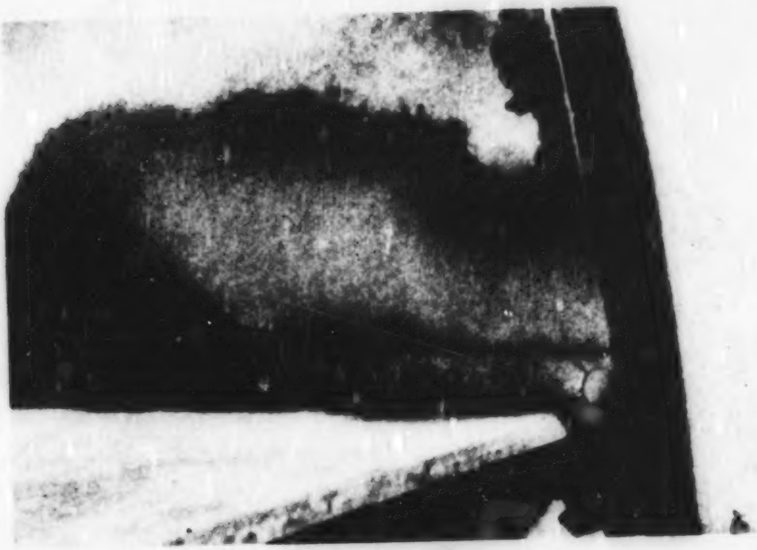


FIGURE 9

Crack in Shroud of Induced-Draft Fan

in the Venturi System

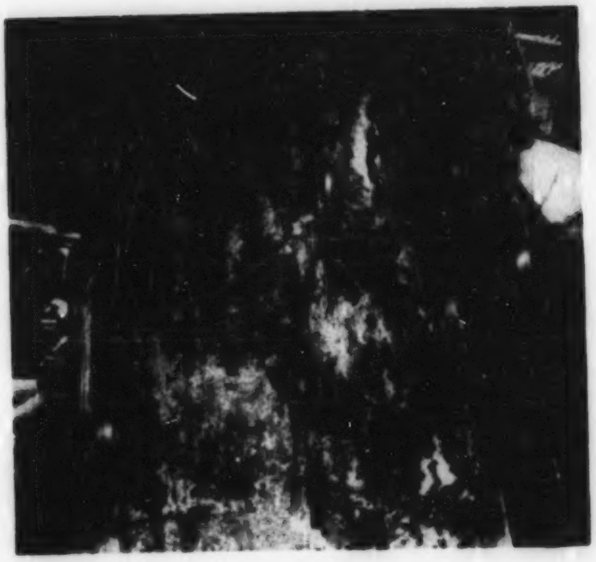


FIGURE 10

Corrosion of Carbon Steel Downcomer

to Tank D-204

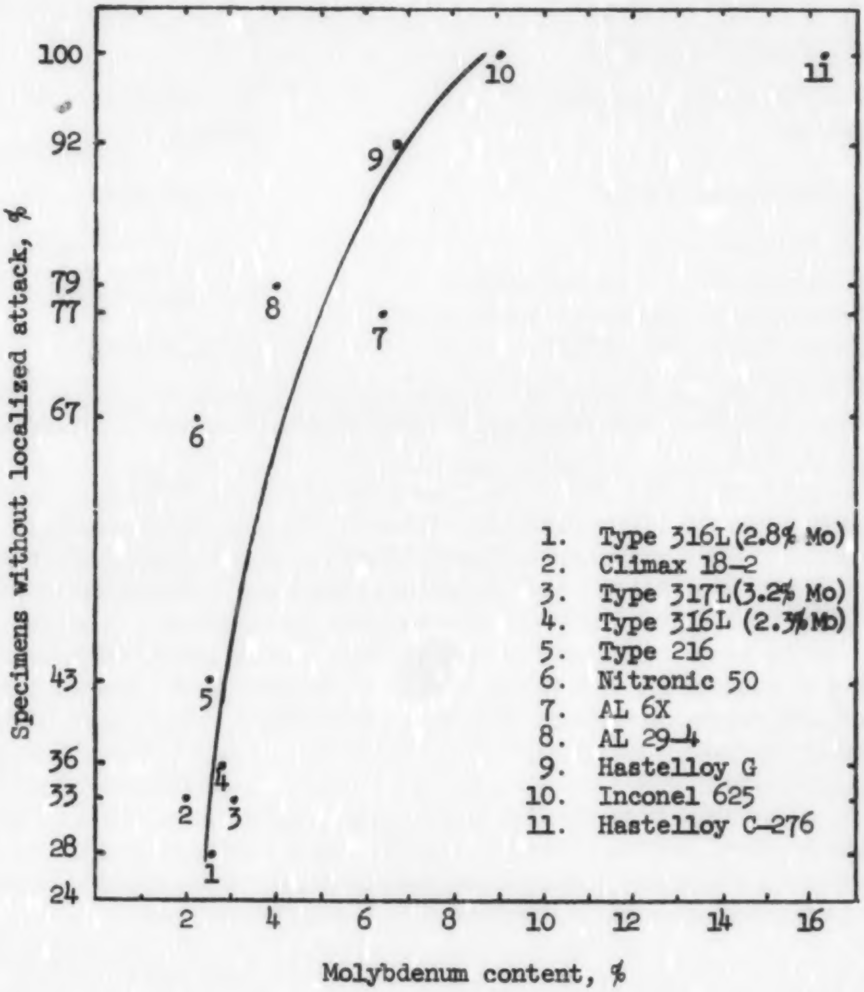


FIGURE 11

MOLYBDENUM CONTENT VERSUS PITTING AND CREVICE CORROSION OF ALLOYS

(See Table IV for analyses of the alloys.)